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Habitat characteristics of *Hydrochara affinis*

잔물땡땡이의 서식처 특성

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Abstract

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Because of increasing activity and perils of mosquito, mosquito control has been a worldwide issue. In particular, biological control using natural enemy of mosquito came to the fore. *Hydrochara affinis* is an aquatic beetle which has recently been focused as natural enemy for biological mosquito control. It is necessary to explore environmental characteristics of its natural habitats for successful mosquito control. Therefore, I surveyed environmental characteristics of its natural habitats (DS), former habitats (FDS) and non-habitats (NDS) which located near natural habitats or had similar landscape. Perennial emergent macrophytes accounted for 85.5% of total plant cover in DS while they accounted for 44.2% and 43.0% in FDS and NDS, respectively. Environmental characteristics such as electrical conductivity and cation concentration of water showed significant differences among three categories, but their ranges in DS were wide. Based on these results, I conclude that perennial emergent macrophyte communities are crucial for habitat selection of *H. affinis* and for continuous mosquito control, it is essential to maintain proper physicochemical environment for macrophyte community.

Keywords : Biological mosquito control, Habitat characteristics, *Hydrochara affinis*, Perennial emergent macrophyte

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Contents

Introduction

Mosquitoes act as a dangerous vector of various deadly diseases such as malaria, yellow fever and encephalitis (Benelli 2015). Recently, rise in temperature and environmental change caused by global warming have expanded the season and the area of mosquito activities (Baek *et al*. 2014). For its increasing perils, mosquito control has been a worldwide issue.

Among diverse control methods, chemical control using insecticide has been used frequently. However, the potential threat of chemical control that toxicity of insecticides can be harmful for human health and the environment has been steadily raised (Benelli 2015). Moreover, continuous spraying might induce resistance against insecticides so that other method should be considered (Hemingway and Ranson 2000). To complement those risks of chemical control, biological control using natural enemies of mosquitoes came to the fore.

Larvivorous fishes have been mainly used as biological mosquito control agents for its high efficiency of predation (Lee 2002; Chandra *et al*. 2008). But those fishes are too predatory to selectively control mosquito larvae and their impact on the ecosystems has not been verified (Lee 2002). Therefore, it became necessary to develop a different kind of biological mosquito control agent to overcome these limitations.

Hydrochara affinis is an aquatic beetle in Hydrophilidae family. Its larvae are predators preying on smaller benthic macroinvertebrates such as mosquito larvae. On the other hand, adult individuals mainly prey on aquatic plants (Baek *et al*. 2014). In addition to this ontogenic diet shift, *H. affinis* larvae can predate mosquito larvae more selectively than larvivorous fishes because it is much smaller than fishes. This feature made *H. affinis* much less likely to disturb the food web than larvivorous fishes and more appropriate biological mosquito control agent. The predation efficiency of *H. affinis* larvae is also outstanding. Third instar larvae of *H. affinis* predates up to 926 *Culex pipiens molestus* larvae and 304 *Ochlerotatus togoi* larvae in one day (Baek *et al*. 2014). These features make *H. affinis* overcome the limitations of larvivorous fish as biological mosquito control agent.

To use *H. affinis* as a biological control agent, it is essential to maintain wild population, identify the proper control site for *H. affinis* and if it is necessary, construct artificial habitats. In order to achieve these processes, environmental characteristics of natural habitats must be identified primarily. However, there are few studies about habitat characteristics of Hydrophilidae family. Especially in the case of *H. affinis*, although some former studies about its morphological and behavioral existed features (Inoda *et al*. 2003; Choi *et al*. 2016), there was no research about proper habitat characteristics. Considering that habitat selection determines abundance and richness of beetles in aquatic macroinvertebrate communities (Binckley and Resetarits 2005), to know the environmental characteristics of natural habitat which might be critical for habitat selection of *H. affinis* is essential for selecting control site to introduce *H. affinis* and constructing artificial habitats to proliferate wild population (Richoux 1994; Vonesh *et al*. 2009; Resetarits and Pintar 2016).

In this study, the survey and analyses about environmental conditions which might affect the inhabitation of *H. affinis* were conducted to provide and specify the utilization plan of *H. affinis* as a biological mosquito control agent. Former studies suggested the inhabitation conditions of aquatic beetles such as chemical characteristics of the water body (Juliano 1991), vegetation structure (Fernández and Kehr 1995; Lutz and Kehr 2017), and microhabitat substrate (Fairchild *et al*. 2003). Based on those conditions proposed by former studies, I investigated items such as physicochemical characteristics of water and soil, community structure of plant and invertebrate communities at study sites.

Materials & Methods

1) Study sites

27 habitats in South Korea were investigated (Fig. 1). I distinguished study sites into three categories of DS (Dwelling Site), FDS (Former Dwelling Site) and NDS (Non-Dwelling Site). In DS, we confirmed the inhabitation of *H. affinis* larvae or adult. In FDS, inhabitation of *H. affinis* had been reported, but has not been confirmed in this study. NDS had very similar landscape characteristics or are located near DS (Table 1). However, the inhabitation had not been reported in NDS and has not been confirmed in this study neither. Field works were conducted from April 2017 to July 2018.

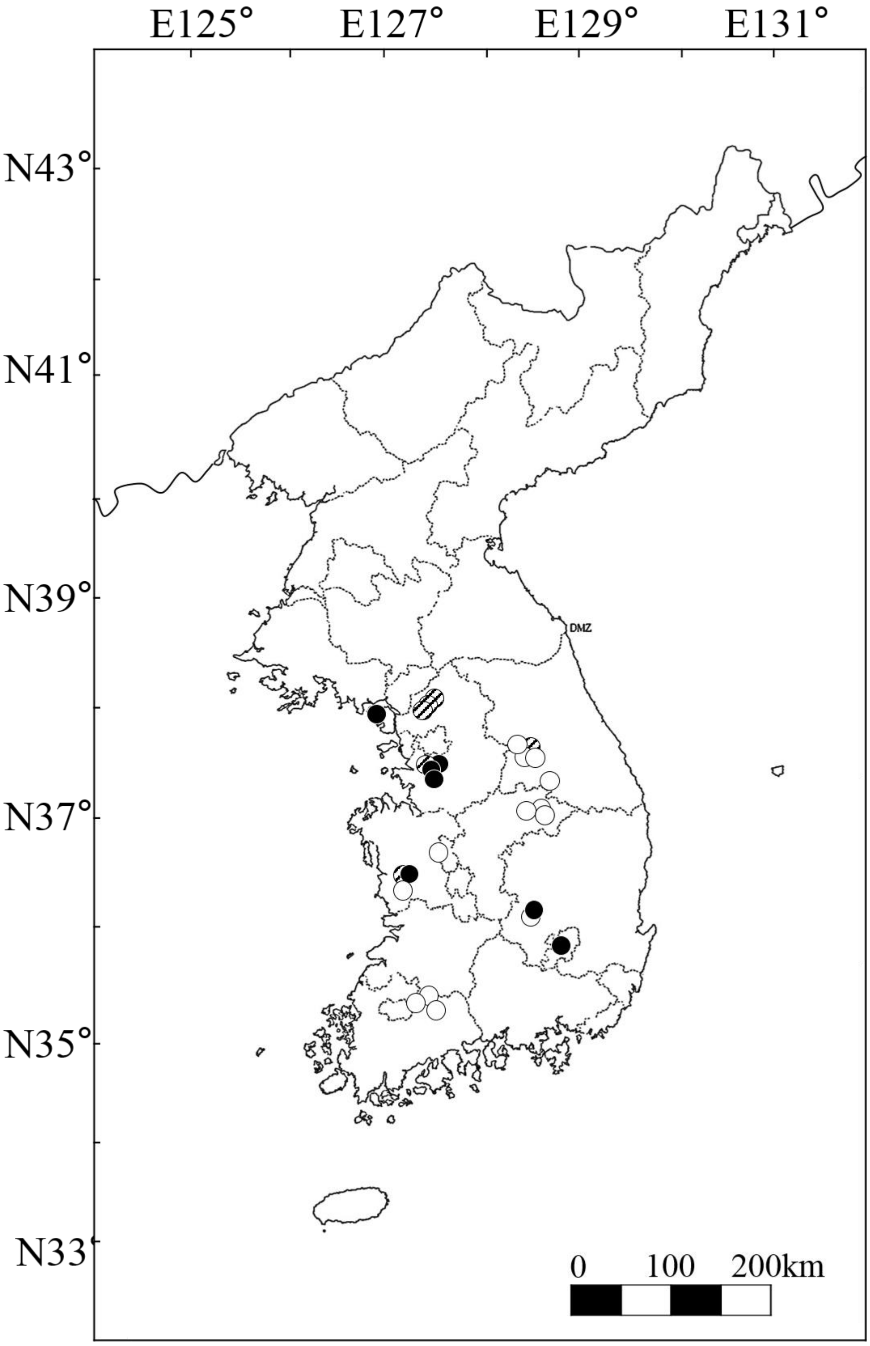

Figure 1. Location of the investigation regions in South Korea. ●, DS; ◍, FDS; ○, NDS.

Table 1. Category, site name and description of study sites.

Category	Region	Site name	Description
DS	Incheon	DS1	Reservoir
	Gunpo	DS2	Pond at paddy field
		DS3	Terraced paddy field
		DS4	Artificial pond
	Buyeo	DS5	Pond at paddy field
	Daegu	DS6	Pond at paddy field
		DS7	Reservoir
	Jecheon	DS8	Pond at paddy field
FDS	Gunpo	FDS1	Artificial pond
	Buyeo	FDS2	Agricultural waterway
	Paju	FDS3	Pond at paddy field
		FDS4	
		FDS5	
	Hoengsung	FDS6	Stream
	Dangjin	FDS7	Stream
NDS	Daegu	NDS1	Reservoir
	Hoengsung	NDS2	Reservoir
		NDS3	Pond at paddy field
		NDS4	Artificial pond
	Dangjin	NDS5	Pond at paddy field
	Yeongwol	NDS6	Reservoir
	Chungju	NDS7	Pond at paddy field
	Danyang	NDS8	
	Gongju	NDS9	Reservoir
	Sunchang	NDS10	Pond at paddy field
	Goksung	NDS11	
	Damyang	NDS12	

2) Geographical features and plant community survey

Because the habitats of *H. affinis* mostly are wetlands with stagnant water, we established the border of sites and drew the vegetation maps of each sites to examine distribution of vegetation and area of each plant community. Site area and plant cover were calculated by Adobe Photoshop CS6 program. The most abundant species were used to name the plant community. In each main plant community, we set 1 m × 1 m quadrats and measured the cover, abundance, and height of each plant species. Identification of plant species followed Lee (2003) and Lee (2006). I categorized plant communities into 14 functional groups by frequency, degree of wetness and growth form (Choung *et al*. 2012, Table 2).

Table 2. Categorization of 14 functional groups of plant communities. FG 4.1 and FG 5.1 did not appear in this study. OBW and FACW refer to obligate wetland plant and facultative wetland plant, FAC, FACU and OBU refer to facultative plant, facultative upland plant and obligate upland plant, respectively (Choung *et al*. 2012).

Frequency	**Degree of wetness**	**Growth form**	**Functional group**
OBW, FACW	Hygrophyte	Annual/Biannual plant	**FG 1.1**
		Perennial plant	**FG 1.2**
		Tree	**FG 1.3**
	Emergent plant	Annual/Biannual plant	**FG 2.1**
		Perennial plant	**FG 2.2**
	Floating-leaf plant	Annual/Biannual plant	**FG 3.1**
		Perennial plant	**FG 3.2**
	Floating plant	Annual/Biannual plant	**FG 4.1**
		Perennial plant	**FG 4.2**
	Submerged plant	Annual/Biannual plant	**FG 5.1**
		Perennial plant	**FG 5.2**
FAC, FACU, OBU		Annual/Biannual plant	**FG 6.1**
		Perennial plant	**FG 6.2**
		Tree	**FG 6.3**

3) Aquatic macroinvertebrate survey

Aquatic macroinvertebrates were collected both quantitatively and qualitatively. For quantitative sampling, aquatic macroinvertebrates were collected three times for each site by using surber net (30 cm × 30 cm). For qualitative sampling, two researchers collected with hand net (2 mm mesh) during about 20 ~ 40 minutes depending on the area of sites. Collected samples were preserved in 80% ethanol. To evaluate species richness, diversity and balance of the community, I calculated species richness index suggested by Margalef (Margalef 1958), Shannon-Wiener diversity Index (Pielou 1969) and the ratio of EPT (sum of the total number of individuals classified as Ephemeroptera, Plecoptera and Trichoptera) and Chironomidae (Plafkin *et al*. 1989).

4) Physicochemical characteristics of water

I collected water sample at each quadrat. Dissolved oxygen in water (DO) was measured at the fields with Kasahara portable DO meter (Model DO-10Z). After samples were transported to laboratory, pH and electrical conductivity (EC) were measured with OHAUS Starter 300 portable pH meter and conductivity meter, respectively. In order to analyze concentration of NO_3-N, NH_4-N, PO_4-P, K^+, Ca^{2+}, Na^+ and Mg^{2+}, water samples were filtered with membrane filter of pore size 0.45 μm. NO_3-N, NH_4-N and PO_4-P concentrations were analyzed by Hydrazine method (Kamphake et al. 1967), indo-phenol method (Murphy and Riley 1962) and Ascorbic acid reduction method (Solorzano 1969) respectively. Cation concentrations were measured by an Atomic Absorption Spectrometer (VARIAN, Model AA240FS).

5) **Physicochemical characteristics of soil**

Soil samples were collected at a depth of 0 – 10 cm from the surface in each quadrat. Soil samples were sieved with a 2 mm sieve (standard sieve #10). Organic matter content was measured by loss on ignition method (LOI; Boyle 2004). NO_3-N and NH_4-N were extracted with 2 M KCl solution (Kim *et al*. 2004), and PO_4-P was extracted with Bray No.1 solution (Bray and Kurtz 1945). Cations were extracted with 1N ammonium acetate solution (Allen *et al*. 1974). For soil pH and conductivity, soil solutions were made up by mixing soil with distilled water at a mass ratio of 1 to 5. NO_3-N, NH_4-N, PO_4-P, K^+, Ca^{2+}, Na^+, Mg^{2+} concentrations, pH and EC in extracted solution were measured by the same methods for water samples.

6) **Statistical analyses**

We first checked normality of data with Shapiro-Wilk test (Shapiro and Wilk 1965). Since most of our data didn't have normality and there were three categories to compare, I used Kruskal-Wallis test for finding significant differences among three categories (Kruskal and Wallis 1952). For characteristics having significant difference, post-hoc test was performed by using Mann-Whitney U test (Mann and Whitney 1947). All statistical processes were performed by using R i386 3.3.2 (R Core Team 2016).

Results and Discussion

1) Geographical features

The area of DS ranged from 92.8 m^2 to 46,080 m^2 (Table 3). Although areas were diverse, *H. affinis* individuals were found in common at emergent macrophyte communities near the borders of sites. Plant coverage also showed large range in DS sites from 32.1% to 96.8% (Table 3). Average site area excluding extreme outlier (DS1) was 348.9 m^2 and average plant coverage in DS sites were 69.71%. Although plant coverage of DS and FDS were higher than NDS, site area (χ^2 = 0.76944, df = 2, p = 0.6806) and plant coverage (χ^2 = 4.0736, df = 2, p = 0.1304) did not show significant differences among three categories (Table 3). It is clear that *H. affinis* do not simply choose their habitat by size of the water body. Also, Fairchild *et al*. (2000) showed that the area of habitat had little effect to the assemblage of aquatic beetles than other habitat characteristics. Therefore, I inferred that size of the habitat and its vegetation cover do not mainly determine the habitat selection of *H. affinis*.

Table 3. Total area, plant coverage and dominant species of study sites.

Category	Site name	Total area (m^2)	Plant coverage (%)	Dominant species
DS	DS1	46,080	32.1	*Zizania latifolia*
	DS2	92.8	68.4	*Typha angustifolia*
	DS3	333.3	96.8	*Erigeron annuus*
	DS4	268.8	64.0	*Humulus japonicus – Erigeron annuus*
	DS5	689.9	75.4	*Zizania latifolia*
	DS6	359.5	86.4	*Trapa japonica*
	DS7	6,203	34.7	*Potamogeton crispus – Leersia japonica*
	DS8	574.2	100.0	*Hydrilla verticillata*
FDS	FDS1	873.5	75.8	*Potamogeton distinctus*
	FDS2	483.7	51.1	*Oenanthe javanica*
	FDS3	257.3	90.8	*Trapa japonica - Utricularia japonica*
	FDS4	809.2	100.0	*Sparganium japonicum*
	FDS5	259.4	100.0	*Trapa japonica*
	FDS6	361.9	67.6	*Persicaria thunbergii - Phragmites japonica*
	FDS7	1,282	66.2	*Humulus japonicas - Zizania latifolia*
NDS	NDS1	4,606	33.7	*Leersia japonica - Persicaria nodosa*
	NDS2	1,152	47.8	Poaceae *spp.*
	NDS3	361.9	69.6	*Trapa japonica*
	NDS4	373.9	92.0	*Nymphoides peltata*
	NDS5	280.9	100.0	*Typha latifolia*
	NDS6	2,095	54.8	*Salix koreensis*
	NDS7	30.3	11.5	*Polygonum thunbergii*
	NDS8	51.4	60.0	*Potamogeton crispus*
	NDS9	367.9	47.1	*Leersia japonica*
	NDS10	24.5	63.6	Poaceae *spp.*
	NDS11	97.1	83.1	*Leersia japonica*
	NDS12	96.6	49.3	*Typha angustifolia*

2) Plant and aquatic macroinvertebrate communities

75 plant communities were analysed. Dominant species with large coverage were *Zizania latifolia* (22.1% of total plant coverage), *Phragmites communis* (14.4%), *Typha angustifolia – Leersia japonica* (12.7%), *Typha angustifolia* (9.0%) and *Leersia japonica* (7.0%). These species all belong to FG 2.2 (Table 2). Communities with other dominant species showed less than 5% of the area of total surveyed communities. In every sites, communities with dominant species of perennial emergent plants (FG 2.2) were distributed in the largest area (Fig. 2). They accounted for 70.2% of total plant coverage. Especially in DS, they accounted for 85.5% of plant coverage, which is almost twice as much as in FDS (44.2%) and NDS (43.0%) (Fig. 2). In general, perennial emergent plant communities located near the boundaries of sites. But it was common that they covered entire space in case of small ponds. The second largest cover was shown by annual/biannual upland plant (FG 6.1) communities (5.41%). In DS, they showed 2.1% of total cover, while they showed 12.4% and 10.6% in FDS and NDS respectively. Upland trees (FG 6.3) were only shown in FDS (14.0%) and NDS (2.7%).

The rate of perennial emergent plant communities showed the most dramatic differences among DS, FDS and NDS (Fig. 2). In our survey, every DS sites had shallow shoreline (> 1 m depth) with dense emergent macrophytes. Perennial emergent plants at shallow shoreline such as *Zizania latifolia* and *Acorus calamus* increase habitat complexity or heterogeneity so that the food item for aquatic macroinvertebrate such as periphyton can colonize and the shelters to evade the predator fish are provided (Fairchild *et al*. 2003; Thomaz *et al*. 2010; Lutz and Kehr 2017). In practice, for *Enochrus vulgaris* and *Enochrus variegatus* which are also in Hydrophilidae family, Byttebier *et al*. (2012) noted that they were mainly associated with greater vegetation cover which could be related to the availability of shelters to avoid predation by fish. Since the threat of predation can affect not only the assemblage but also the oviposition rate of Hydrophilidae individuals, the hiding place is essential in their natural habitats (Batzer and Wissinger 1996; Resetarits 2001; Resetarits 2018). Dense emergent macrophyte community can perform this role very well. Thus, the existence of emergent macrophyte community at the shoreline of habitat can be a main preferred microhabitat component of *H. affinis*. Moreover, since free-swimming mosquito larvae prefer dense plant stands also (Orr and Resh 1992, Thullen *et al*. 2002), this common preference for habitat has an important meaning in mosquito control. Considering this common preference, it would be efficient to introduce *H. affinis* as biological mosquito control agent to the habitat with high spatial heterogeneity produced by emergent macrophytes such as *Zizania latifolia* and *Typha angustifolia.*

In case of aquatic macroinvertebrate communities, neither of species richness (χ^2 = 2.4423, df = 2, p = 0.2949), Shannon-Wiener index (χ^2 = 0.95476, df = 2, p = 0.6204) and EPT/C (χ^2 = 0.59779, df = 2, p = 0.7416) showed significant differences among three categories. The average of species richness index in DS, FDS and NDS were 5.20, 5.79 and 4.83 respectively. And the average value of Shannon-Wiener index in DS, FDS and NDS were 3.10, 2.88 .and 3.19 respectively, and the average of EPT/C were 1.80, 0.84 and 3.76 respectively. The range of species richness index, Shannon-Wiener index and EPT/C in DS were 3.39 ~ 7.39, 2.27 ~ 3.95 and 0.00 ~ 3.36 (Fig. 3).

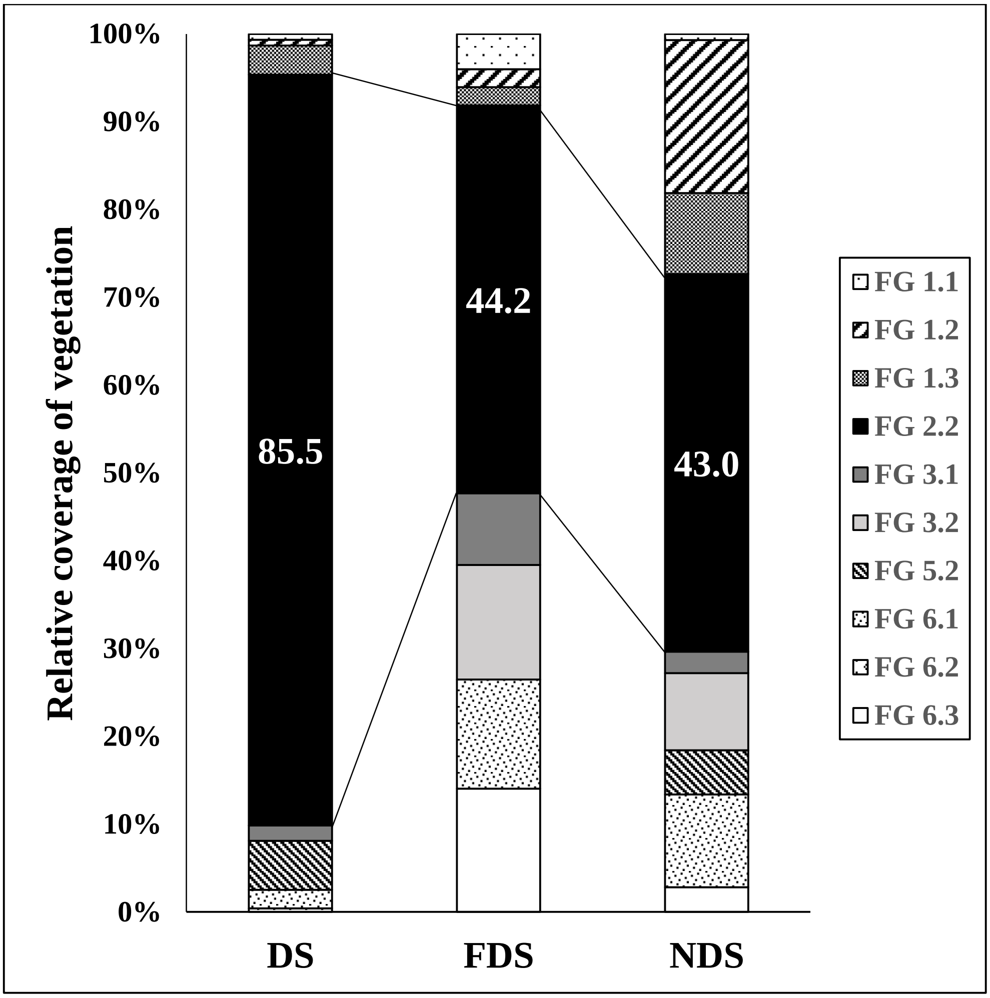

Figure 2. Comparison of relative coverage of functional groups among DS, FDS and NDS. Definition of each functional group (FG) in legend is described in Table 2.

These wide ranges of biological indices show that it is not critical to retain certain level of richness, diversity and balance among macroinvertebrate communities for the habitat selection of *H. affinis*. Though the species richness patterns of aquatic beetles were correlated with the remaining richness value (Sánchez-Fernández et al. 2006), the inhabitation pattern of *H. affinis* did not seem significantly correlated with species richness. Low EPT/C value indicates the possibility of environmental stress (Plafkin *et al*. 1989). Our results indicate that *H. affinis* can be introduced in the habitat with poor diversity and environmental stress, which mosquito larvae also thrive.

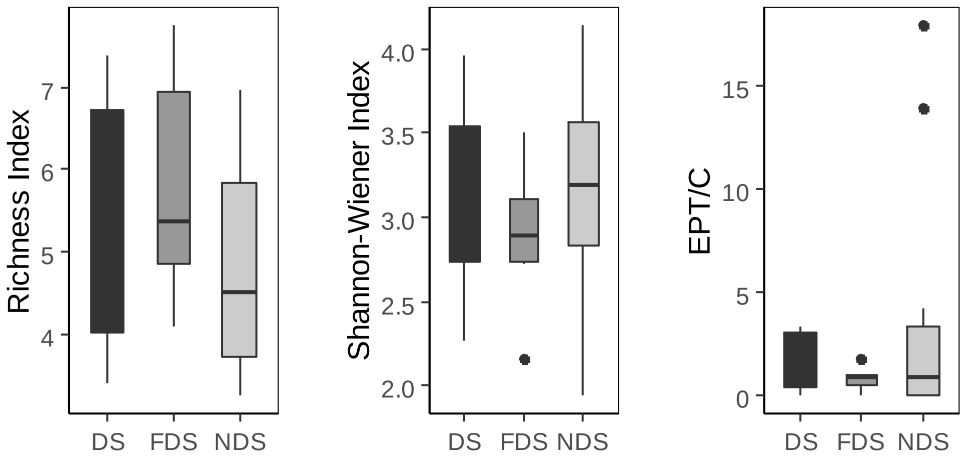

Figure 3. Box-whisker plots showing species richness index, Shannon-Wiener diversity index and EPT/C of aquatic macroinvertebrate community among DS, FDS and NDS; DS, n = 8; FDS, n = 6; NDS, n = 11.

3) Physicochemical characteristics of water

EC (χ^2 = 6.8946; df = 2; p = 0.03183) and K^+ (χ^2 = 10.557; df = 2; p = 0.0051), Ca^{2+} (χ^2 = 12.925; df = 2; p = 0.001561), Na^+ (χ^2 = 9.6002; df = 2; p = 0.008229), Mg^{2+} (χ^2 = 6.0986; df = 2; p = 0.04739) concentrations were significantly higher in DS than FDS and NDS. Other variables did not show differences among three categories. Average ECs were 523.24 μS/cm, 264.22 μS/cm, 251.24 μS/cm in DS, FDS and NDS respectively. K^+, Ca^{2+}, Na^+, Mg^{2+} concentrations were 7.18 mg/L, 14.91 mg/L, 18.43 mg/L, 6.98 mg/L in DS, 2.14 mg/L, 2.83 mg/L, 5.67 mg/L, 2.76 mg/L in FDS and 1.26 mg/L, 5.71 mg/L, 6.58 mg/L, 2.88 mg/L in NDS, respectively (Fig. 4).

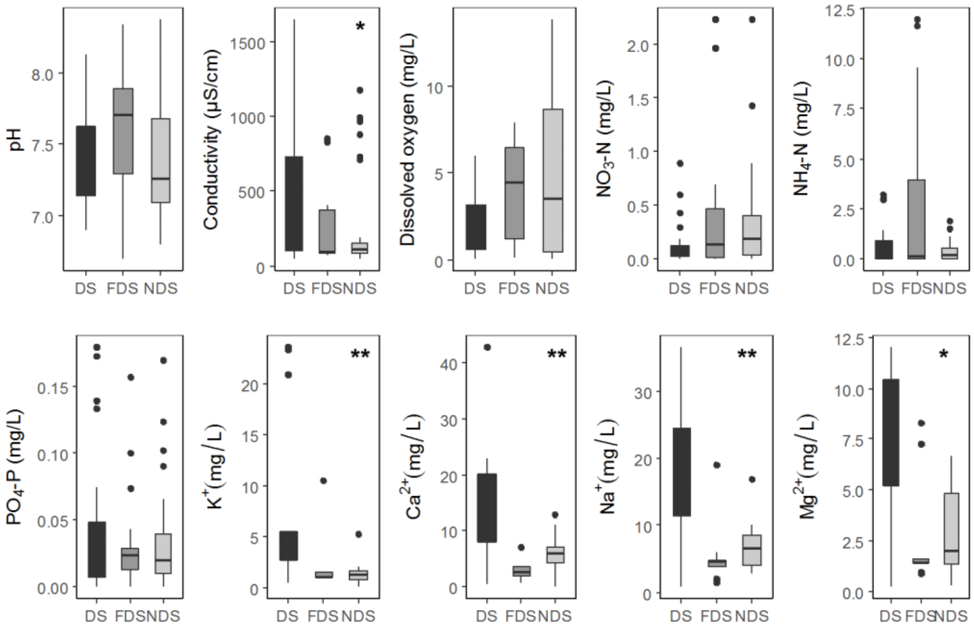

Figure 4. Box-whisker plots showing environmental variables of water samples among DS, FDS and NDS sites. P-values derived from Kruskal-Wallis test were shown (* : $p < 0.05$, ** : $p < 0.01$); DS, n = 21; FDS , n = 18; NDS, n = 34. In case of cations; DS, n = 14; FDS, n = 9; NDS, n = 21.

Juliano (1994) noted that physicochemical characteristics of water such as pH might affect species composition of aquatic macroinvertebrate community. In case of *Graphoderus liberus*, an aquatic beetle in Dytiscidae family, its assemblage composition did not show relation to pH (Arnott *et al*. 2006). Bendell and McNicol (1987) also noted that *G. liberus* could appear at fishless lakes irrespective of pH. In our results, although conductivity and cation concentrations showed differences among DS, FDS and NDS, the ranges of all surveyed physicochemical characteristics of water in DS were large (Fig. 4.). This indicates that there is no specific level of cation concentration that *H. affinis* prefer in particular. Especially in the case of larvae, they breathe through air on the surface of the water, so the water quality does not significantly affect its inhabitation (Baek *et al*. 2014). In addition, emergent macrophytes such as *Zizania latifolia* and *Typha angustifolia* can also grow in water with wide range of conductivity and cation level (Kwon *et al*. 2006). Therefore, we could infer that habitat selection of *H. affinis* is not critically affected by physicochemical characteristics of water.

4) Physicochemical characteristics of soil

NH_4-N (χ^2 = 10.186, df = 2, p = 0.00614), K^+ (χ^2 = 7.0737, df = 2, p = 0.02911) and Mg^{2+} (χ^2 = 6.7501, df = 2, p = 0.03422) showed significant differences among three categories (Fig. 5). In spite of the differences, NH_4-N and Mg^{2+} in DS showed a large range (0.07 ~ 27.72 mg/kg, 7.10 ~ 414.90 mg/kg). In case of K^+, DS (7.44 ± 0.58 mg/kg) and FDS (8.13 ± 1.16 mg/kg) showed a little bit higher value than NDS (6.89 ± 1.27 mg/kg). The ranges of soil characteristics in DS were wide overall

Compared to FDS and NDS, DS showed fine soil texture such as clay loam and silt loam (Table 4). However, half of surveyed DS showed thicker soil texture such as loam, sandy clay loam and sandy loam (Table 4). These results indicate that *H. affinis* itself is habitable regardless of the physicochemical characteristics of soil. However, macrophytes such as *Zizania latifolia* and *Typha angustifolia* were distributed at soil with high silt ratio such as loam and silt loam (Kwon *et al*. 2006). Considering the inhabitation of *H. affinis* might be greatly influenced by emergent macrophytes and the distribution of wetland plants is dependent on environmental factors of soil and water (Heegard *et al*. 2001), it can be crucial to maintain appropriate soil condition for emergent macrophytes to manage the habitats of *H. affinis* (Nam *et al*. 2018). Therefore, since their artificial habitats for maintaining and proliferating wild population should be maintained with high cover of emergent macrophyte communities, physicochemical characteristics of water and soil environment need not to be greatly considered if the growth conditions for emergent macrophytes are satisfied.

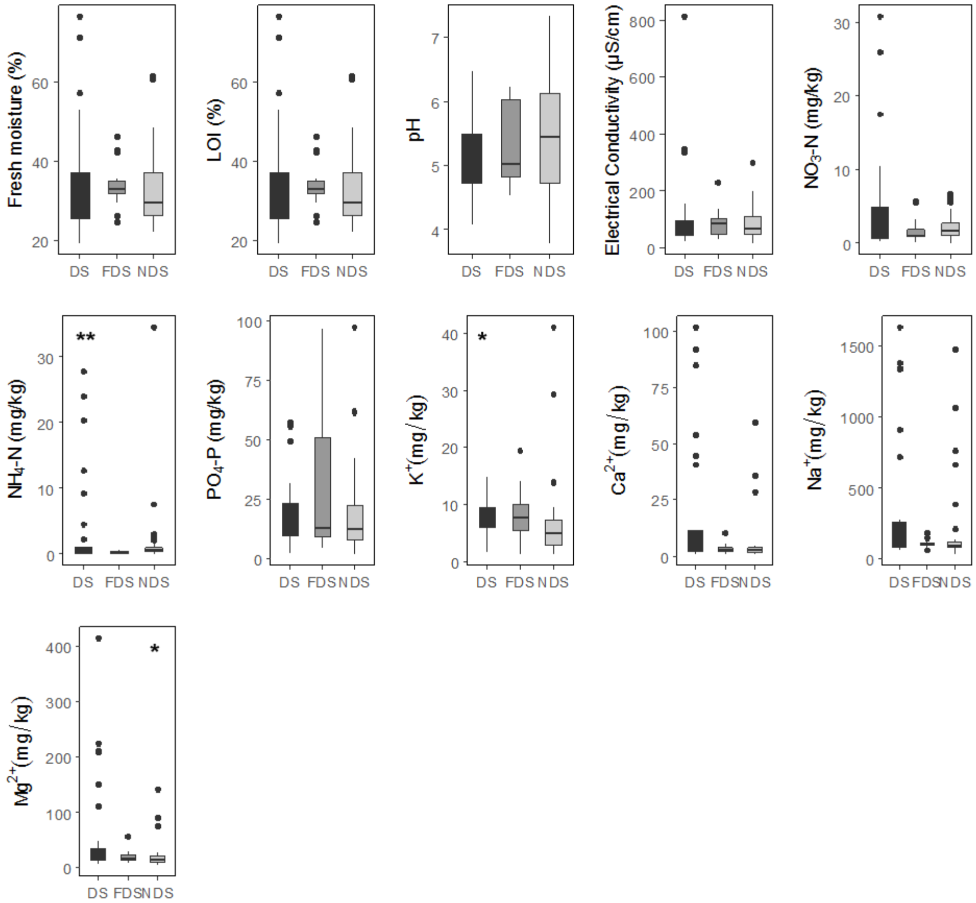

Figure 5. Box-whisker plots showing environmental variables of soil samples among DS, FDS and NDS; DS, n = 29; FDS, n = 16; NDS, n = 38.

Table 4. Soil texture ratio (%) of DS, FDS and NDS; DS, n = 8; FDS. n = 5; NDS, n = 10.

Soil texture	DS	FDS	NDS
Clay loam	25.0	-	-
Silt loam	25.0	-	-
Loam	25.0	100.0	80.0
Sandy clay loam	12.5	-	10.0
Sandy loam	12.5	-	10.0

Conclusion

Among all surveyed environmental characteristics, the cover (85.5% of total plant cover) of perennial emergent macrophytes might be the main determinants of the inhabitation of *H. affinis*. Therefore, for efficient biological mosquito control, *H. affinis* should be introduced as biological mosquito control agent at habitats with high cover of emergent macrophytes. Although other characteristics do not affect the inhabitation of *H. affinis* significantly, it is essential to maintain the environmental conditions for emergent macrophyte communities for the prosperity of *H. affinis* populations because the distribution of wetland plants is dependent on environmental factors of soil and water.

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국문초록

최근 증가하고 있는 모기의 활동과 위험성에 의해, 모기 방제는 전세계적으로 주목받고 있는 분야 중 하나다. 특히, 모기의 천적을 이용한 생물학적 모기 방제가 그 중에서도 많은 관심을 받고 있다. 잔물땡댕이(*Hydrochara affinis*)는 물땡땡이속에 속하는 수서 딱정벌레로서, 최근 모기의 천적 생물로서 생물학적 모기 방제제로의 이용 가능성이 대두되고 있는 종이다. 그러나 성공적인 모기 방제를 위해서는 잔물땡땡이를 생물학적 모기 방제제로 이용하기 전에 잔물땡땡이의 자연 서식처 환경을 파악하는 것이 우선적으로 이루어져야 한다. 그러므로, 본 연구에서는 잔물땡땡이의 자연 서식처(DS), 전 서식처(FDS)와 자연서식처 가까이 위치해 있거나 비슷한 경관을 지닌 비서식처(NDS)의 환경 요인을 조사하였다. 다년생 대형 정수식물이 FDS에서는 전체 식피율의 44.2%, NDS에서는 43.0%를 차지한 반면, DS에서는 85.5%를 차지했다. 수환경의 전기전도도나 양이온 농도와 같은 환경 요소가 세 서식처 분류군간에 유의미한 차이를 보였으나, DS에서 그러한 요인들의 범위는 매우 넓었다. 이러한 결과에 비추어 볼 때, 다년생 정수식물 군락이 잔물땡땡이의 서식처 선택에 주요한 영향을 끼치는 요인이므로, 성공적이고 계속적인 모기 방제를 위해서는 대형정수식물 군락을 위한 적절한 환경이 갖춰져야 할 것이라는 결론을 내렸다.

주요어 : 다년생 대형정수식물, 서식처 특성, 생물학적 모기 방제, 잔물땡땡이(*Hydrochara affinis*),

학 번 : 2016-24754

감사의 글

잠깐 눈을 감았다 뜬 것만 같은데 어느새 2년 반이 지나버렸네요. 즐거운 날들은 빠르게 가버린다는데 정말 그런가 봅니다. 이 즐거운 시간들을 함께 만들어주신 분들께 감사의 말씀을 드리고 싶습니다.

우선 아무런 준비도 되어 있지 않은 채 자연대에서 불쑥 찾아온 저를 받아주시고 짧지 않은 시간 동안 따뜻하게 지도해주신 김재근 교수님께 감사드립니다. 교수님께는 2년 반 내내 미숙한 모습만 보여드린 것 같아 죄송할 따름입니다. 비록 변변찮은 모습밖에 못 보이는 제자였지만, 교수님께서 제게 말씀해주신 모든 것들과 제게 보여주신 모습들을 가슴 깊숙이 간직하고 졸업 뒤의 모습으로 보답하겠습니다. 2년 반 동안의 지도에 깊이 감사드립니다. 생소한 내용임에도 관심있게 논문을 봐주시고 인자한 미소와 함께 논문의 부족한 점을 짚어 주신 생물교육과의 네 분 교수님께도 감사의 말씀을 드립니다.

전국의 습지를 돌아다니면서 함께 잔물땡땡이를 찾아다녔던 이보은 쌤, 이보쌤이 안 계셨다면 어떻게 됐을지 상상도 못 하겠어요. 면허가 없어서 운전도 못 도와드리고, 말주변도 없어서 재미도 없고, 조사도 미숙하고.. 2년 동안 못난 후배 데리고 다니느라 힘드셨을 거라고 생각합니다. 그래도 이보쌤의 노고 덕분에 제가 이렇게 졸업할 수 있게 됐어요. 2년 동안 너무 감사했는데 이제야 부족하지만 감사의 말씀을 드릴 수 있게 되어 기쁩니다. 정말 감사합니다. 앞으로도 남편 분이랑 행복하게 사시는 모습 보여주세요.

입학 전부터 저를 굉장히 따뜻하게 맞아 주신 남보은 쌤, 남보쌤에게는 뭐든지 언제나 받기만 하고 제대로 보답한 적이 없는 것 같아요. 비록 자연대로 유학가시는 바람에 떨어져 있던 시간이 길긴 했지만, 그래도 제 생태방 생활에 있어서 남보쌤이 미친 영향은 굉장히 큽니다. 가르침은 물론이고, 즐거운 시간도 많이 만들어 주셨으니까요. 남보쌤이 고생하시고 후배들에게 베푸시는 만큼, 앞으로 하시는 실험도 모두 잘 되고, 늘 행복한 꽃길만 걸으셨으면 좋겠습니다. 제가 졸업 이후 어떻게 될 지는 모르겠지만, 앞으로도 종종 만나서 제가 생태방

에 있던 시절처럼 즐거운 시간을 보낼 수 있었으면 좋겠습니다. 꼭이요.

후배인지 선배인지 가끔 헷갈리지만 일단은 후배인 현준이. 내가 생태방에서 가장 많은 시간을 같이 보낸 사람이 아닐까 싶네. 수업도 같이 많이 들었고, 배드민턴도 같이 치고 하는 사이에 어느 새 내가 졸업을 해버렸네. 내가 생태방에 들어온 지 얼마 되지 않았을 때 먼저 친근하게 다가와줘서 고맙게 생각하고 있어. 덕분에 편하게 석사 생활을 할 수 있었던 것 같아. 지난 한 해 동안 방장으로서 너무 수고 많았어. 일도 이것저것 하느라고 많이 바빠 보였는데, 하고 있는 일, 졸업까지 모두 다 스무스하게 풀렸으면 좋겠다고 진심으로 바라고 있어.

쉴 틈없이 나를 자극시켰던 환상의 콤비 혜경이와 가연이. 너희 둘은 정말.. 최고야.. 물론 좋은 의미..로.. 너희들과 얘기할 땐 마치 탁구를 치는 기분이었어. 너희들은 빠른 템포로 경쾌하게 공을 치듯이 얘기했지만 나는 그걸 받아치지 못 했지. 그래서 '얘네들은 내가 엄청 답답하겠지?'라고 생각했는데, 그래도 내가 졸업하면 아쉬울 것 같다고 하는 걸 보니까 공을 치는 맛은 있었나 보네. 그래, 직접 말은 못 했지만, 나도 졸업 이후에 너희들을 자주 못 봐서 아쉬울 것 같아. 내 인생에 너희들만큼 폭풍 같은 사람은 없었으니까. 나중에 봤을 때도 지금처럼 폭풍 같은 기세를 보여주길 기대할게. 앞으로 남은 1년 동안도 즐겁게 지내고, 재밌는 주제 찾아서 순탄히 졸업할 수 있기를 바래. 선배로서 너희들한테 해 준 건 별로 없고 너희들이 나를 도와주기만 한 것 같아서 미안하고 고마워.

같이 졸업하는 시현쌤, 시현쌤이랑 같이 졸업하게 돼서 정말 다행이라고 생각하고 있어요. 시현쌤도 논문 쓰고 졸업 준비하느라 바쁘셨을 텐데 저를 굉장히 많이 챙겨주셔서 너무 감사합니다. 그래도 제가 나름 선배인데 선배 노릇 한 번 못 해 본 것 같네요. 캐나다 가셔도 시현쌤이라면 그 누구보다도 잘 지낼 것 같다는 예감이 들어요. 시현쌤과 자녀분들의 앞길에 행복한 일만 있기를 바랄게요.

생태방의 든든한 기둥 홍문기 박사님. 박사님께서는 저를 많이 챙겨주

셨는데 제가 그 만큼 다가가지 못해서 너무 아쉬워요. 박사님처럼 강인한 사람은 처음 보는 것 같아서, 박사님이랑은 언제나 더 친해지고 싶은 마음이 있었는데, 머뭇거리던 새 졸업하게 되어 버렸네요. 제가 생태방에 있는 동안, 예은이가 태어나고 자라면서 함께 축하하고 기쁨을 나눌 일이 참 많았죠. 하지만 박사님의 힘드셨던 시간은 나누지 못한 것 같아 죄송합니다. 지금 생각해보면 제가 조금이라도 더 다가가야 했었다고 생각해요. 그래도 박사님은 보란 듯이 이겨내셨고, 다가올 시련도 거뜬히 물리치실 거라고 믿어요. 제가 졸업한 이후에도 박사님의 호쾌한 웃음 소리를 들을 일이 많았으면 좋겠습니다. 앞으로도 아내분과 예은이와 함께 행복하게 사시는 모습 보여주세요.

모르는 게 없는 생태방의 지식백과 호님, 생물교육과의 새로운 교무조교 락연쌤께도 2년 반 동안 저를 챙겨주셔서 감사하다는 말씀을 드리고 싶습니다.

논문이 완성되기까지 도움을 주신 상지대학교의 이황구 박사님과 DMZ 생태연구소의 김재현 선생님께도 감사의 말씀을 드립니다.

그리고 언제나 묵묵히 나를 믿어주는 사랑하는 우리 가족에게도 진실한 감사의 마음을 담아 이렇게 감사의 글을 올립니다.

모두들 정말 감사합니다. 모두 여러분 덕분입니다.

임세혁 올림.