韓国南部の農村地帯の水草相、および水草相と土地利用・水質との関係

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Michiko Shimoda[1*] and Jong-Suk Song[2] : **Aquatic flora of rural areas and its relation to land use and water quality in southern Korea**

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Abstract

We carried out field research in the southern Korean Peninsula and Jeju Island, South Korea to describe the aquatic flora and its habitat of the Korean rural areas, including 32 sites in the peninsula and 16 sites on the island. The sites of the peninsula are irrigation ponds and reservoirs for rice fields. The sites of the island are ponds for the drinking water of domestic animals, and irrigation and washing of local people. The study sites with agriculturally intensive watersheds had high values of electric conductivity (EC) > 40 mS/m. We found 8 free-floating taxa, 9 floating-leaved taxa and 14 submerged taxa. Eleven taxa (e.g. *Trapa japonica*) were found in both areas. Thirteen taxa (e.g. *Euryale ferox*) were restricted to the peninsula. Seven taxa (e.g. *Potamogeton natans*) were restricted to the island. Although most of the taxa were found in waters with various EC values, several species (e.g. *Nymphoides indica*) were confined to waters with EC < 30 mS/m. Most of the confirmed taxa in this study are found in Japan. The abundant species (e.g. *T. japonica*) commonly dominate in nutrient-rich ponds in Japan. The aquatic flora of the study area was characterized by species characteristic of a wide distribution and/or eutrophic water. The aquatic flora includes seven species regarded as threatened in Korea. It also includes 15 Japanese threatened species, and 9 of them are rice weeds. Our study shows that ponds of Korean rural areas support diverse aquatic plants including rare and threatened species.

Key words : irrigation pond, Jeju Island, Korean Peninsula, rice field, threatened species.

Introduction

Rice has been the major crop cultivated in Korea and Japan for a long time. In both countries, natural wetlands are very limited because many freshwater wetlands have been converted into fields for rice and other human uses. Recently, the importance and value of irrigated lands including rice fields, irrigation ponds and channels are emphasized from the viewpoint of biodiversity (Ministry of the Environment, Government of Japan 2008).

In Japan, aquatic flora (e.g. Shimoda 1983, 2005a; Kadono 1984; Kunii 1991; Naka 2001) and vegetation (e.g. Shimoda 1985, 1986; Kadono 1987) of irrigation ponds have been reported from various localities. The relationship between aquatic flora of irrigation ponds and pond water quality was also studied (e.g. Hamashima 1983, 2008; Kunii 1991; Shimoda and Hashimoto 1993; Shimoda 1997; Mineta and Hidaka 2002; Shimoda and Kagawa 2009). Thus there have been many studies on aquatic plants of irrigation ponds in Japan.

In South Korea, aquatic flora has been reported from large rivers (e.g. Chung and Choi 1981, 1983, 1985; Lee et al. 1987; Chung et al. 1989) and large-scale artificial lakes (e.g. Choi and Lee 1987; Kim et al. 1991; Lim et al. 2005; Kang et al. 2007) of the Korean Peninsula. Only a few studies on aquatic plants of small ponds have been carried out in the peninsula (Chung and Choi 1987; Ji 2008). Therefore studies on aquatic plants of Korean irrigation ponds remain limited. A plant list of Jeju Island by Nakai (1914) included many aquatic and wetland plants. However, detailed study on aquatic plants of the island has not yet been conducted. In North Korea, although Kolbeck and Dostálek (1996) described aquatic plant communities of water basins, the aquatic flora and vegetation of the northern part of the Korean Peninsula are little known.

To describe the aquatic flora and its habitat of the Korean rural area, we carried out field research in the southern Korean Peninsula and Jeju Island in August 2008. In this paper, we present the aquatic flora. We also discuss its distribution in relation to the environment, and the floral difference between the two study areas. Finally, we compare our results with Japanese rural aquatic flora to clarify the characteristics of Korean rural aquatic flora.

Study sites

Figure 1 shows our 48 study sites: 32 sites in the southeastern part of the Korean Peninsula (Fig. 1A, Appendix 1) and 16 sites on Jeju Island (Fig. 1B, Appendix 2). Sites 1-8 of the peninsula are situated in Gyeongsangbuk-do Province, and sites 9-32 are in Gyeongsang-nam-do Province. Annual mean temperatures of Daegu, Busan and Jeju are 14.1, 14.7 and

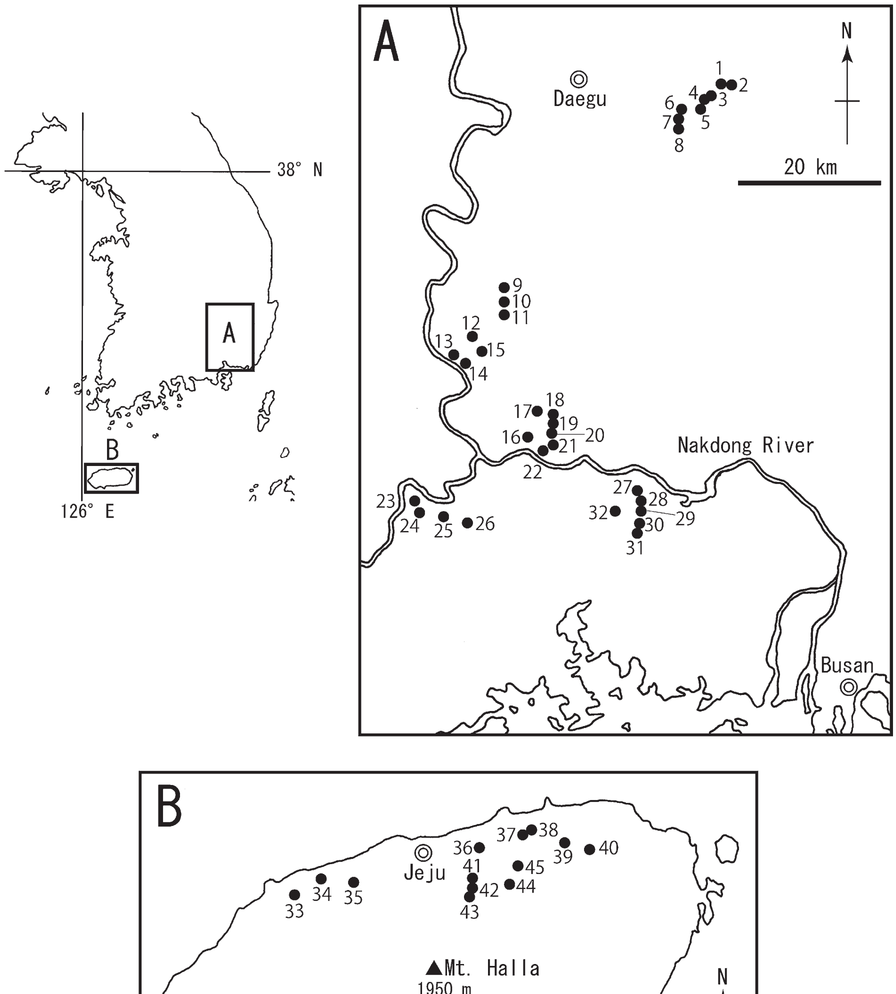

Fig. 1. Map of the southern Korea showing the study sites. A: Southeastern part of the Korean Peninsula, B: Jeju Island.

15.8 °C, and their annual mean precipitations are 1064.4, 1519.1 and 1497.6 mm respectively (Korea Meteorological Administration 2011).

According to Ramsar Convention on Wetlands (2008), a pond is water body with its size below 8 ha, and a reservoir is generally over 8 ha. In our study area of the peninsula, numerous irrigation ponds and reservoirs are distributed at the foot of hills and mountains, and on the plains. The study sites 1-32 are distributed from 5 to 130 m in altitude. Among them, 22 sites are irrigation ponds less than 8 ha, and 9 sites are reservoirs over 8 ha. The top three large reservoirs are site 29 of 285 ha, site 12 of 128 ha and site 28 of 75ha. Sites 23 and 24 were regarded as natural swamp by Chung and Choi (1987). However they are surrounded by embankments and arable lands, and not complete natural wetlands. All the study sites except site 22 were used for irrigation of rice fields. Some of them were used partially to irrigate upland cultivation such as orchards and vegetables. Site 22 was a ditch surrounded by cultivated and abandoned rice fields. Therefore all study sites in the peninsula were influenced by human activities, especially by agricultural activities.

Jeju Island is a volcanic island. On the island, rice fields are very limited because of the lack of irrigation water (Takano 1996). Many small ponds were constructed for the drinking water of domestic animals, irrigation for upland crops and washing of local people (Izumi 1966). Sites 33-48 are distributed from 6 to 331 m in altitude. The largest reservoir (34) is ca. 10 ha. Most of the study sites are small ponds below 1 ha, and used for irrigation of upland crops and drinking of domestic animals. Site 37 is a small garden pond of a house. Site 48 is a ditch surrounded by rice fields.

Methods

We investigated aquatic plants and water quality on 2-6 August 2008 in the peninsula (Fig. 1A) and on 7-9 August 2008 on the island (Fig. 1B). Water temperature, electric conductivity (EC) and pH of the surface water were measured, because they are important factors that give an outline of the water quality (Japan Society for Analytical Chemistry, Hokkaido 1981). The measurements were carried out near the spillway of each pond and reservoir with portable EC meter (Yokogawa SC72) and pH meter (Yokogawa PH71). Water quality was measured at more than one point at the sites of large areas (8, 12, 28, 29) and at the sites with different kinds of land uses and vegetation in their watersheds (2, 4, 9-11, 32, 33). At sites 40 and 45 on the island, we could not measure water quality because there was no water there. We got measured values from 60 points in total (Appendixes 1, 2). Values of EC were calibrated at 25 °C.

Growth condition and distribution of each species within each site were recorded. “Aquatic plants” in this paper are the plants which were described in “Aquatic plants of Japan” (Kadono 1994). Besides the vascular plants in Kadono (1994), we recorded *Ricciocarpos natans* (L.) Corda (bryophyte) and *Chara braunii* Gmelin (charophyte) as aquatic plants. Species identification and nomenclature mainly follow Kadono (1994). Identification of *Vallisneria* L. and *Utricularia* L. is according to Na et al. (2008a) and Na et al. (2008b), respectively.

Results

Environment and water quality of the study sites

The watersheds of study sites included forests, agricultural lands, houses and paved roads. Figure 2 shows the distribution of EC and pH values of the study sites. The average, minimum and maximum values of EC were 24.7 mS/m, 7.9 mS/m at sites 19, 39 and 55.2 mS/m at site 6 respectively. The average, minimum and maximum values of pH were 7.90, 6.18 at site 11 and 10.52 at site 47 respectively. All pH values of the island were more than 7.

Two sites (19, 39) indicated EC values less than 10 mS/m. Site 19 is situated at the foot of a mountain. Its watershed included forest, grassland and upland fields. Site 39 was surrounded by forest, grassland and paved road. Among seven sites with EC > 40 mS/m, five sites (4, 6-8, 11) had watersheds partly forested, but their watersheds were also occupied by rice fields, upland fields, orchards, paved roads

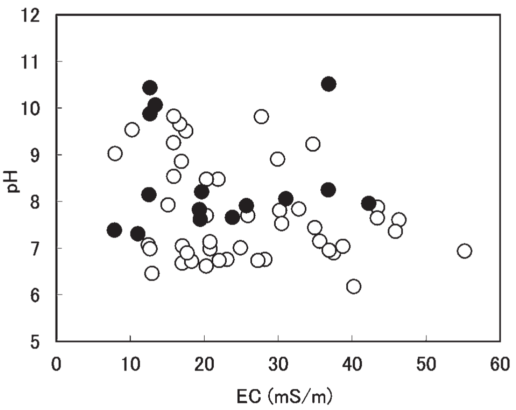

Fig. 2. Electric conductivity (EC) and pH of study sites. ○: Korean Peninsula, ●: Jeju Island.

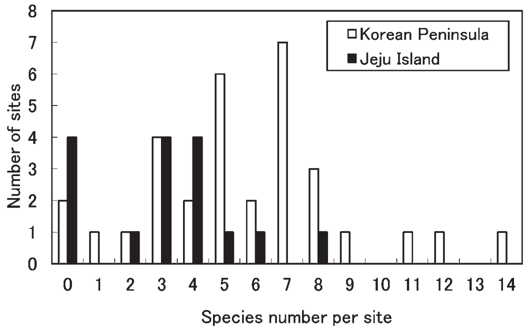

Fig. 3. The number of true aquatic species per study site. True aquatic plants consist of free-floating, floating-leaved and submerged plants (Seddon 1972), and were found in 42 sites.

and houses. Other two sites (22, 33) had watersheds without forest. Site 22 was surrounded by cultivated and abandoned rice fields. Site 33 was surrounded by paved road and upland fields. The sites with EC of 10-40 mS/m had watersheds including forests and diverse anthropogenic environments such as grasslands, rice fields, upland fields, orchards, paved roads and factories.

Aquatic plants

Table 1 shows the plants found in the study sites. The species of Table 1 are arranged according to their life forms by Sculthorpe (1967) and Kadono (1994). The emergent species of the table include amphibious and emergent-wetland species by Kadono (1994).

Because certain species were difficult to identify accurately without reproductive parts, some taxa were identified to genus only. *Utricularia* of the study sites was similar to Japanese *U. australis* R. Br. (a synonym *U. tenuicalis* Miki). Na et al. (2008b) reported that *U. tenuicalis* is distributed widely, and *U. japonica* Makino, similar to *U. tenuicalis,* is very rare in Korea. Therefore we tentatively assigned *Utricularia* in our study to *U. australis*. We confirmed two types of *Vallisneria*, *V. asiatica* Miki and the plant similar to *V. denseserrulata* (Makino) Makino. We regarded the latter as *V. spinulosa* S. Z. Yan following the study of Na et al. (2008a).

We found 8 free-floating taxa, 9 floating-leaved taxa, 14 submerged taxa and 33 emergent taxa. Twenty-four taxa (e.g. *Trapa japonica* Flerov) occurred in both areas. Twenty-three taxa (e.g. *Euryale ferox* Salisb.) were restricted to the peninsula. Seventeen taxa (e.g. *Potamogeton natans* L.) were restricted to the island. Therefore there is clearly a floristic difference between the two study areas. The aquatic flora of study sites includes 18 species designated as threatened in Korea and Japan. Categories of threatened species are shown in Table 1. Seven species are threatened in Korea, and 15 species are threatened in Japan. Four species among them are threatened in both countries.

Free-floating, floating-leaved and submerged species were called “true aquatic species” (Seddon 1972). We found 31 true aquatic taxa at 42 sites: 30 sites in the peninsula and 12 sites on the islands. The remaining six sites contained only emergent taxa, and no true aquatic taxa. Figure 3 shows the number of true aquatic species per site. Junam reservoir (site 29: 285 ha) contained 14 species, the largest number. The four sites of more than eight species were reservoirs with the area >10 ha in the peninsula. Among the sites on the island, site 46 (0.5 ha), with the largest number of species, contained eight species. Floating-leaved *Trapa japonica*, *Euryale ferox*, *Nymphoides indica* (L.) O. Kuntze, and free-floating *Spirodela polyrhiza* (L.) Schleid, *Lemna paucicostata* Hegelm., *Hydrocharis dubia* (Bl.) Backer, *Salvinia natans* (L.)

Table 1. Aquatic plants found in 48 study sites

Life form and species	和名	Threatened species categories			Number of sites		
		Korea[1]	Korea[2, 4]	Japan[3, 4]	Peninsula	Jeju	Total
Free-floating							
Surface-floating							
Ricciocarpos natans	イチョウウキゴケ			NT		1	1
Salvinia natans	サンショウモ			NT	13		13
Hydrocharis dubia	トチカガミ		LC	NT	14		14
Lemna paucicostata	アオウキクサ				18	4	22
Spirodela polyrhiza	ウキクサ				20	3	23
Wolffia globosa	ミジンコウキクサ				1		1
Submerged free-floating							
Ceratophyllum demersum	マツモ				19	1	20
Utricularia australis	イヌタヌキモ			NT	3		3
Floating-leaved							
Potamogeton natans	オヒルムシロ					5	5
Potamogeton distinctus	ヒルムシロ				3		3
Potamogeton cristatus	コバノヒルムシロ			VU		5	5
Euryale ferox	オニバス	II	VU	VU	8		8
Nymphaea sp.	スイレン（園芸品種）					5	5
Trapa japonica	ヒシ				27	9	36
Trapa natans var. *japonica*	オニビシ				2		2
Nymphoides peltata	アサザ			NT	6		6
Nymphoides indica	ガガブタ			NT	3	4	7
Submerged							
Chara braunii	シャジクモ			VU	1	3	4
Hydrilla verticillata	クロモ				15	1	16
Ottelia alismoides	ミズオオバコ		LC	VU		1	1
Vallisneria asiatica	セキショウモ				2		2
Vallisneria spinulosa	セキショウモ属の1種				2		2
Potamogeton malaianus	ササバモ				1	1	2
Potamogeton crispus	エビモ				11	2	13
Potamogeton pusillus	イトモ			NT	2		2
Potamogeton sp. 1	ヒルムシロ属 sp. 1				2		2
Potamogeton sp. 2	ヒルムシロ属 sp. 2				1		1
Najas graminea	ホッスモ					1	1
Najas japonica	イトトリゲモ			NT		1	1
Najas sp.	イバラモ属 sp.				5	1	6
Myriophyllum sp.	フサモ属 sp.				5	1	6
Emergent							
Marsilea quadrifolia	デンジソウ			VU	2	3	5
Alisma canaliculatum	ヘラオモダカ					2	2
Sagittaria trifolia	オモダカ		DD		2		2
Monochoria korsakowii	ミズアオイ			NT	1		1
Monochoria vaginalis	コナギ				1	1	2
Murdannia keisak	イボクサ				3	6	9
Leersia japonica	アシカキ				22	2	24
Paspalum distichum	キシュウスズメノヒエ				5	3	8
Phragmites australis	ヨシ				22	3	25
Phragmites japonica	ツルヨシ				4		4
Pseudoraphis ukishiba	ウキシバ				1	1	2
Zizania latifolia	マコモ				12	1	13
Acorus calamus	ショウブ		LC		2	2	4
Sparganium erectum	ミクリ		VU	NT		1	1
Sparganium sp.	ミクリ属 sp.				1		1
Typha latifolia	ガマ				1		1
Typha angustifolia	ヒメガマ				13	4	17
Typha sp.	ガマ属 sp.					1	1
Bolboschoenus fluviatilis subsp. *Yagara*	ウキヤガラ				2		2
Bolboschoenus maritimus	コウキヤガラ				1		1
Eleocharis kuroguwai	クログワイ				1		1
Eleocharis dulcis	シログワイ				1	2	3
Eleocharis mamillata	ヌマハリイ					2	2

Table 1. Continued

Eleocharis acicularis var. *longiseta*	マツバイ			2	2
Eleocharis sp. 1	ハリイ属 sp. 1		1		1
Eleocharis sp. 2	ハリイ属 sp. 2			1	1
Schoenoplectus mucronatus subsp. *robustus*	カンガレイ			10	10
Schoenoplectus validus	フトイ		2	4	6
Polygonum amphibium	エゾノミズタデ	EN	1		1
Nelumbo nucifera	ハス		7	1	8
Ludwigia ovalis	ミズユキノシタ			5	5
Elatine triandra	ミゾハコベ			2	2
Limnophila sessiliflora	キクモ			1	1
Number of species			47	41	64

1) Endangered species category (Ministry of Environment, Republic of Korea 2006).
2) Rare plant category (Korea National Arboretum 2008)
3) Red List species category of Ministry of the Environmen (Ministry of the Environment, Government of Japan 2012)
4) EN: Endangered, VU: Vulnerable, NT: Near threatened, LC: Least concern, DD: Data deficient.

All. were dominant species and covered most of the water surface in several sites.

Aquatic plant distribution and water quality

True aquatic plants (free-floating, floating-leaved and submerged plants) complete their life cycle in the water. They are expected to depend more directly on water quality than emergent plants which generally grow along the edges of the water and also grow occasionally in terrestrial habitats. Therefore, we show the relationship between water quality (EC and pH) and distribution of true aquatic plants, except for emergent plants. Figures 4-6 show the distribution of the plants found in more than two sites by their life forms. Cultivated *Nymphaea* sp. was excluded from Fig. 5. *Trapa* spp. (Fig. 5) and *Najas* spp. (Fig. 6) include the species found in less than three sites. The species found in the sites where water quality was measured at more than one point have more measured values than their site numbers. For example, *Salvinia natans* occurred at 13 sites (Table 1) but its measured values are 17 (Fig. 4), because water quality was measured at more than one point at two sites (12, 28). The species found in the sites without enough water to measure water quality have less measured values than their site numbers (e.g. *Nymphoides indica* in Fig. 5 occurred at four sites on the island, but one of the sites was dried up).

Many taxa occurred in water with a wide range of EC. However *Utricularia australis* (Fig. 4), *Potamogeton natans*, *P. cristatus* Regel et Maack and *Nymphoides indica* (Fig. 5) were restricted to the water with lower EC, mostly below 30 mS/m. Among the species found in less than three sites, *Trapa natans* var. *japonica* Nakai, *Ottelia alismoides* (L.) Pers., *Potamogeton pusillus* L., *Najas graminea* Del. and *N. japonica* Nakai were distributed in the water with EC < 30 mS/m.

The majority of the taxa were distributed in the water with pH 6-10. However *Potamogeton natans*, *P. distinctus* A. Benn., *P. cristatus* (Fig. 5), *Chara braunii* and *Myriophyllum* sp. (Fig. 6) were not distributed in the water with pH < 7. *Utricularia australis* (Fig. 4) and *P. natans* (Fig. 5) showed narrow distribution of pH values. *Utricularia australis* (Fig. 4) was restricted to lower values of EC and pH. No plant was restricted to very high values of EC and pH.

Discussion

Characteristics of water quality and aquatic flora of study sites

Toivonen and Huttunen (1995) stated that EC is a good overall parameter of the general nutrient status, and that EC has a high correlation with total nitrogen and phosphorus. In the studies of Japanese irrigation ponds, a correlation between EC and nutrient concentrations was reported (e.g. Kasuya et al. 1989; Kunii 1991; Kagawa et al. 2008). In three studies on water quality of Japanese ponds (Kasuya et al. 1989; Kunii 1991; Naka 2001), the average, minimum and maximum values of EC were 9.1-11 mS/m, 1.5 mS/m (Kunii 1991)

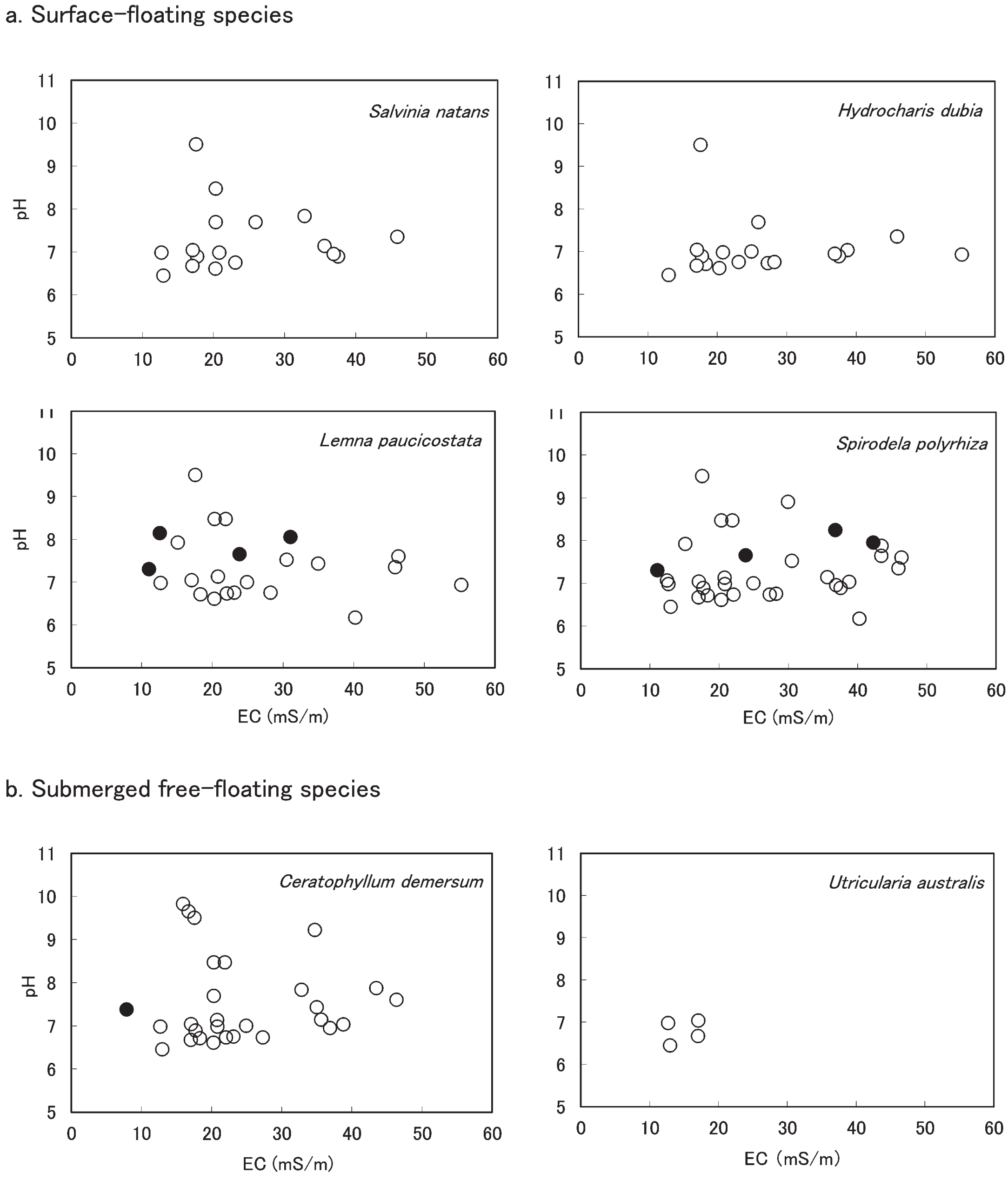

Fig. 4. Relationship between the distribution of free-floating species, EC and pH. ○: Korean Peninsula, ●: Jeju Island.

and 33.6 mS/m (Naka 2001) respectively. In the studies of the ponds in western Japan by the first author, most of the EC values were less than 20 mS/m (Shimoda 1993, 1997, 2005a; Shimoda and Ideguchi 1993). However in an area dominated by citrus orchards, the EC values of pond water were 12.2-41.6 mS/m and its average value was 24.5mS/m (Kagawa et al. 2008). The values of total nitrogen (TN) and total phosphorus (TP) of the ponds in this area were extremely higher than the values of the areas without orchard (Kasuya et al. 1989; Shimoda and Hashimoto 1993; Naka 2001).

In our study area in Korea, the average, minimum and maximum values of EC were 24.7 mS/m, 7.9 mS/m and 55.2 mS/m respectively.

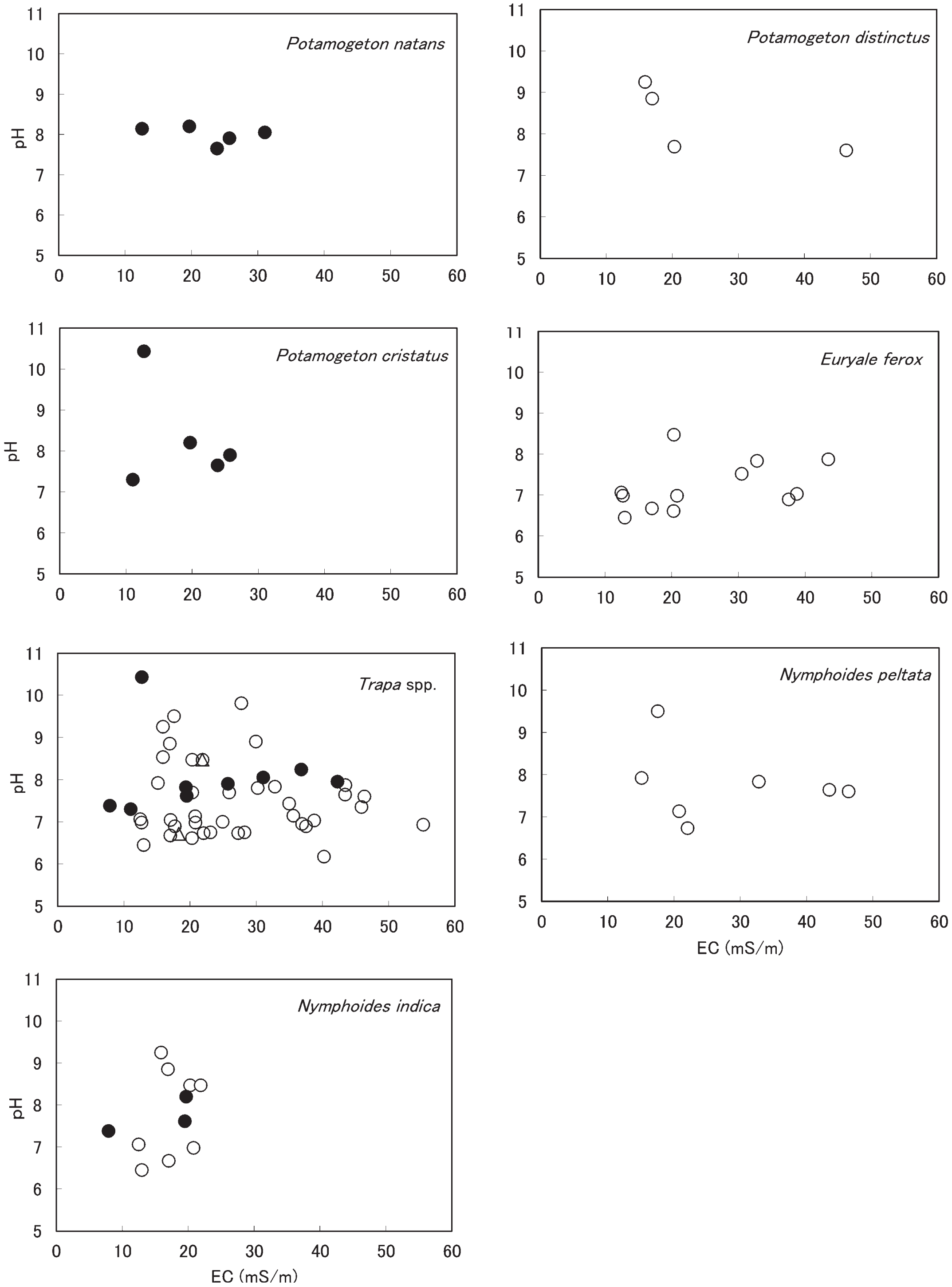

Fig. 5. Relationship between the distribution of floating-leaved species, EC and pH. Open mark: Korean Peninsula, filled mark: Jeju Island. *Trapa* spp. includes *T. japonica* (○, ●) and *T. natans* var. *japonica* (△).

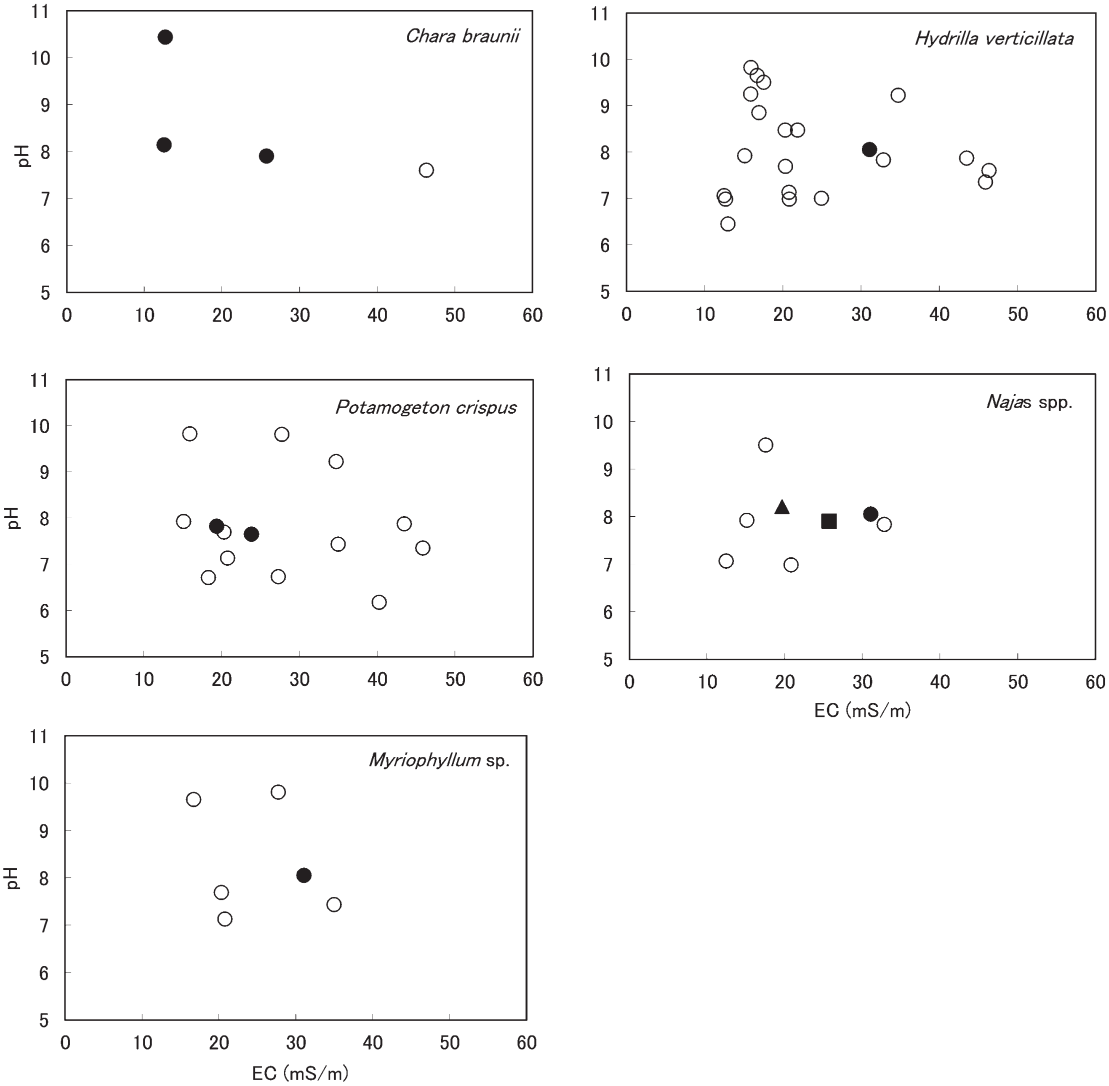

Fig. 6. Relationship between the distribution of submerged species, EC and pH. Open mark: Korean Peninsula, filled mark: Jeju Island. *Najas* spp. includes *Najas* sp. (○, ●), *N. graminea* (▲) and *N. japonica* (■).

Many sites showed high EC > 20 mS/m (Fig. 2), and the range of EC values was similar to the value range of the area dominated by citrus orchard (Kagawa et al. 2008). Most of the sites in our study had watersheds which were occupied partly or completely by agricultural land use such as rice fields, upland fields and orchards. Therefore high EC values suggest that our Korean study sites included many nutrient-rich ponds and reservoirs.

Most of the confirmed taxa in the present study are distributed in Japan. The abundant true aquatic species found in more than 10 sites in Table 1 (e.g. *Trapa japonica*) very commonly dominate in Japanese nutrient-rich ponds (Shimoda and Hashimoto 1993; Kadono 1994; Naka 2001; Hamashima 2008; Shimoda and Kagawa 2009). *Spirodela polyrhiza*, *Trapa japonica* and *Euryale ferox* were reported to have wide growth range and are found even in the ponds with high EC > 30mS/m in Japan (Naka 2001; Mineta and Hidaka 2002). Among the species in Table 1, *Utricularia australis*, *Potamogeton pusillus* and *Najas graminea* were restricted to nutrient-poor ponds in Japanese studies (Shimoda and Hashimoto 1993; Naka

2001; Shimoda and Kagawa 2009). In our study, these three species were rare and occurred in the sites with EC < 20 mS/m (Figs. 4, 6).

Brasenia schreberi J. F. Gmel, *Nymphaea tetragona* Georgi and *Potamogeton fryeri* A. Benn. are known to be characteristic species in weak-acidic and nutrient-poor water (Shimoda and Hashimoto 1993; Naka 2001; Hamashima 2008). Although these three species are distributed in Korea, they were not found in our study sites. Kim (1996) reported that optimal condition for the growth of *B. schreberi* in Korea was near neutral pH, low conductivity and low turbidity. Among the study sites of Kim (1996), *B. schreberi* was distributed in the water with pH 6.4-7.0 and EC with 6.6-13.9 mS/m. This result is similar to the results of studies in Japan (Shimoda 1997, 2005a; Naka 2001). In our study sites, waters with near neutral pH and low EC <10 mS/cm were very limited (Fig. 2). Compared with Japanese aquatic flora, our study area was characterized by the species of wide distribution and/or eutrophic water.

In Japanese irrigation ponds, alien aquatic plants such as *Egeria densa* Planch., *Elodea nuttallii* (planch.) St. John and *Eichhornia crassipes* (Mart.) Solms-Laub. occur and flourish in many places, particularly in eutrophic waters (Kadono 1994). In the present study, we did not find any alien species except *Nymphaea* sp., which was obviously planted for an ornamental purpose.

Threatened aquatic species of Korea and Japan

The aquatic flora of study sites (Table 1) includes seven species regarded as threatened in Korea. It also includes 15 Japanese threatened species. Four species among them are threatened in both countries. The remaining 11 Japanese Red List species are common in Korea. The Japanese threatened species in Table 1 include the following nine species which are known as rice field weeds (Kasahara 1951; Kadono 1994): *Ricciocarpos natans*, *Salvinia natans*, *Hydrocharis dubia*, *Utricularia australis*, *Chara braunii*, *Ottelia alismoides*, *Najas japonica*, *Marsilea quadrifolia* L. and *Monochoria korsakowii* Regel et Maack. Most of them were also regarded as rice field weeds in Korea (Nakai 1914; Chung 1956). We investigated aquatic flora in Gyeongsangbuk-do Province, southeastern Korea in 1989, and found *S. natans* and *M. quadrifolia* in five irrigation ponds (Shimoda 1990). Many aquatic species of nutrient-rich water, which are threatened in Japan now, are still distributed widely in Korean rural areas.

Brasenia schreberi is regarded as threatened in Korea. Its endangered species category is II (Ministry of Environment, Republic of Korea 2006) and rare plant category is VU (Korea National Arboretum 2008). The species was not found in the study sites. The species is common in unpolluted ponds and lakes (Kadono 1994), and not regarded as threatened in Japan. It suggests that ponds, reservoirs and lakes, which are suitable for the characteristic species of nutrient-poor water, are not common in the rural areas in southern Korea.

The diversity of Japanese aquatic plants has been reduced by filling, structural modification and water pollution (Kadono 1994). Yamasaki and Hayashi (2004) showed the possibility of the effect of herbicides on the disappearance of *Euryale ferox*. Therefore wide-spread of herbicides in Japan is thought to affect the decline of Japanese aquatic plants. Many sites of this study are regarded to be nutrient-rich, like the ponds surrounded by citrus orchards in Japan (Shimoda and Kagawa 2009). However Korean nutrient-rich ponds are still the habitats of many Japanese Red List species. There is a possibility that differences in use and management of irrigation ponds and use of herbicides in both countries resulted in the differences of aquatic flora of both countries.

Conclusions

The most species-rich site was Junam reservoir (site 29: 285 ha), which had the largest area among the study sites. However, small ponds were also the habitats of diverse aquatic plants. Many of the confirmed species showed wide distribution with water quality. A few species such as *Utricularia australis* (Fig. 4) and *Nymphoides indica* (Fig. 5) were found only in water with low EC values. Therefore nutrient-poor ponds with low EC are particularly valuable as the habitats of diverse aquatic plants.

There is a big possibility that pond filling, water pollution, structural modification and pond abandonment will produce negative effects on aquatic plants, as in Japanese rural areas (Shimoda 2005b). On Jeju Island, we saw several abandoned small ponds without water. Our study shows that ponds of Korean rural areas support diverse aquatic flora including rare and threatened species. Therefore, detailed and urgent surveys on aquatic plants of rural areas are required, especially on small water bodies.

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下田路子[1]・宋　鍾碩[2]：韓国南部の農村地帯の水草相、および水草相と土地利用・水質との関係

韓国の農村地帯の水草相と水草の生育環境を把握することを目的に、朝鮮半島南部32か所と済州島16か所、計48か所において植物と水質の調査を行った。朝鮮半島の調査地は水田灌漑用のため池であり、済州島の調査地は家畜の飲料用と灌漑や洗い物用の池である。調査地のうち、農地に囲まれた池は、電気伝導度（EC）が40mS/m以上の高い値を示した。両地域で浮遊植物8種、浮葉植物9種、沈水植物14種を確認した。このうちヒシなど11種は朝鮮半島と済州島に共通であったが、オニバスなど13種は朝鮮半島、オヒルムシロなど7種は済州島のみに分布し、両地域の植物相に違いがあった。広範囲のEC値に分布する種が多かったが、ガガブタなどの数種はECが30mS/m以下の水域に分布が限られていた。ヒシなどの確認地点が多い種は、日本の富栄養な水域に繁茂する水草であった。調査地の水草相は、生育範囲の広い種と富栄養な水域の種で特徴づけられた。確認種には7種の韓国の絶滅危惧種が含まれていた。また15種の日本の絶滅危惧種も含まれ、そのうちの9種が水田雑草であった。今回の調査結果は、韓国の農村地帯のため池が、稀少種や絶滅危惧種を含む多様な水草の生育地として貴重な存在であることを示している。

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Appendix 1. Locations and brief environmental information of study sites in Korean Peninsula

Site No.[1]	Latitude (N)	Longitude (E)	Type[2]	Main land use of surrounding area	EC (mS/m)[3]	pH
1	35° 51' 09.9"	128° 50' 59.5"	Pond	Forest, grassland, orchard	34.9	7.44
2 a	35° 51' 03.4"	128° 51' 55.1"	Pond	Forest, grassland, orchard	16.7	9.66
2 b	35° 51' 00.0"	128° 51' 49.5"	Pond	Forest, orchard	15.9	9.83
3	35° 50' 15.1"	128° 49' 20.5"	Pond	Forest, orchard	20.3	7.70
4 a	35° 50' 06.5"	128° 49' 12.2"	Pond	Forest, grassland, paved road	27.7	9.82
4 b	35° 50' 08.3"	128° 49' 15.8"	Pond	Forest, grassland	43.4	7.65
5	35° 49' 24.7"	128° 48' 52.6"	Pond	Forest, grassland, orchard, paved road, factory	30.5	7.53
6	35° 49' 23.2"	128° 47' 20.6"	Pond	Forest, orchard, upland fields	55.2	6.94
7	35° 49' 01.8"	128° 47' 02.7"	Pond	Forest, grassland, upland fields	45.8	7.36
8 a	35° 48' 40.6"	128° 47' 03.7"	Reservoir	Paved road	38.7	7.04
8 b	35° 48' 46.4"	128° 46' 55.8"	Reservoir	Forest, orchard	43.4	7.88
9 a	35° 36' 17.3"	128° 28' 18.9"	Pond	Forest, grassland	18.3	6.72
9 b	35° 36' 13.6"	128° 28' 24.8"	Pond	Forest, grassland, houses	27.2	6.74
10 a	35° 35' 17.5"	128° 28' 33.0"	Pond	Forest, rice fields	22.0	6.74
10 b	35° 35' 18.5"	128° 28' 21.5"	Pond	Forest, grassland, rice fields	20.7	7.14
11 a	35° 34' 49.9"	128° 28' 30.5"	Pond	Forest, rice fields, upland fields, houses	40.2	6.18
11 b	35° 34' 51.6"	128° 28' 22.8"	Pond	Forest, rice fields	30.2	7.81
12 a	35° 32' 57.0"	128° 25' 14.2"	Reservoir	Forest, embankment	37.5	6.90
12 b	35° 32' 54.8"	128° 25' 08.5"	Reservoir	Forest, grassland	35.6	7.15
12 c	35° 32' 56.7"	128° 24' 59.4"	Reservoir	Forest	36.9	6.96
13	35° 31' 17.5"	128° 23' 12.7"	Pond	Forest, rice fields, upland fields	20.2	6.62
14	35° 31' 08.1"	128° 24' 08.5"	Reservoir	Forest, rice fields	23.1	6.76
15	35° 31' 31.3"	128° 26' 22.0"	Reservoir	Forest, grassland, rice fields, factory	32.8	7.84
16	35° 24' 43.5"	128° 31' 26.9"	Pond	Grassland, rice fields, paved road	25.9	7.70
17	35° 26' 16.3"	128° 31' 48.4"	Pond	Rice fields, paved road	29.9	8.91
18	35° 25' 30.8"	128° 32' 51.1"	Pond	Forest, grassland, upland fields	15.9	8.54
19	35° 25' 12.6"	128° 32' 50.2"	Pond	Forest, grassland, upland fields	7.9	9.03
20	35° 24' 57.3"	128° 32' 46.7"	Pond	Forest, orchard, upland fields	10.2	9.54
21	35° 24' 00.0"	128° 32' 52.0"	Pond	Forest, upland fields	34.7	9.23
22	35° 23' 48.6"	128° 32' 19.9"	Ditch	Rice fields, abandoned rice fields	46.3	7.61
23	35° 20' 24.7"	128° 20' 03.7"	Reservoir	Forest, rice fields	17.7	6.9
24	35° 19' 05.5"	128° 21' 01.1"	Pond	Forest, rice fields	17.0	7.05
25	35° 18' 30.6"	128° 22' 50.8"	Pond	Forest, rice fields	12.6	6.99
26	35° 18' 10.9"	128° 25' 08.8"	Reservoir	Forest, rice fields, paved road	15.1	7.93
27	35° 20' 47.2"	128° 39' 45.9"	Reservoir	Rice fields	17.5	9.51
28 a	35° 20' 29.5"	128° 40' 14.3"	Reservoir	Rice fields	12.4	7.07
28 b	35° 19' 53.9"	128° 40' 21.9"	Reservoir	Paved road	20.3	8.48
29 a	35° 18' 29.5"	128° 40' 38.8"	Reservoir	Forest, embankment	20.8	6.99
29 b	35° 18' 31.8"	128° 40' 41.4"	Reservoir	Forest, embankment	17.0	6.68
29 c	35° 18' 39.6"	128° 40' 48.4"	Reservoir	Embankment	12.9	6.46
29 d	35° 19' 32.9"	128° 40' 26.9"	Reservoir	Houses, paved road	21.8	8.48
30	35° 18' 01.2"	128° 40' 14.7"	Pond	Forest, grassland, paved road	28.2	6.76
31	35° 17' 59.3"	128° 40' 12.8"	Pond	Grassland, paved road	24.9	7.01
32 a	35° 18' 35.3"	128° 38' 51.9"	Pond	Forest, orchard	15.8	9.26
32 b	35° 18' 32.7"	128° 38' 49.5"	Pond	Orchard	16.9	8.86

[1] Number in Fig. 1.
[2] Pond is below 8 ha, and reservoir is over 8 ha (Ramsar Convention on Wetland 2008).
[3] Calibrated at 25°C.

Appendix 2. Locations and brief environmental information of study sites on Jeju Island

Site No.[1]	Latitude (N)	Longitude (E)	Type[2]	Main land use of surrounding area	EC (mS/m)[3]	pH
33 a	33° 27' 16.1"	126° 20' 49.0"	Pond	Grassland, upland fields, paved road	42.2	7.96
33 b	33° 27' 19.7"	126° 20' 52.5"	Pond	Upland fields, paved road	36.8	8.25
34	33° 28' 14.6"	126° 23' 07.9"	Reservoir	Forest, paved road	13.4	10.07
35	33° 28' 14.2"	126° 25' 34.3"	Pond	Grassland	12.7	9.88
36	33° 30' 19.9"	126° 38' 00.6"	Pond	Upland fields, houses, paved road	19.3	7.83
37	33° 31' 11.8"	126° 39' 51.6"	Pond	Orchard, lawn, house	12.5	8.15
38	33° 31' 23.5"	126° 40' 05.4"	Pond	Forest, upland fields	19.4	7.62
39	33° 30' 30.5"	126° 43' 01.6"	Pond	Forest, grassland, paved road	7.9	7.39
40	33° 30' 12.2"	126° 44' 23.7"	Pond	Forest, paved road	na[4]	na
41	33° 28' 10.6"	126° 36' 22.8"	Pond	Forest, paved road	12.6	10.44
42	33° 28' 10.6"	126° 36' 22.8"	Pond	Forest	11.0	7.31
43	33° 27' 58.4"	126° 36' 17.3"	Pond	Forest, grassland	25.7	7.91
44	33° 28' 03.1"	126° 38' 52.1"	Pond	Forest, grassland	19.6	8.21
45	33° 28' 28.0"	126° 39' 30.9"	Pond	Forest, grassland, upland fields	na	na
46	33° 15' 30.5"	126° 16' 43.4"	Pond	Forest, upland fields	31.0	8.06
47	33° 13' 27.2"	126° 17' 40.7"	Pond	Forest, grassland, upland fields	36.8	10.52
48	33° 15' 08.6"	126° 32' 34.9"	Ditch	Rice fields	23.8	7.66

[1] Number in Fig. 1.
[2] Pond is below 8 ha, and reservoir is over 8 ha (Ramsar Convention on Wetland 2008).
[3] Calibrated at 25°C.
[4] Not analyzed.