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Effects of environmental factors on *Sparganium emersum* and *Sparganium erectum* colonization in two drainage ditches with different maintenance

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ABSTRACT

In the Niheishimizu and Ooshimizu sections of the town of Misato in the Akita Prefecture, Northern Japan, there are many abundant spring water areas. *Sparganium* (*Sparganium emersum* and *Sparganium erectum*) species are widely distributed in the irrigation water that fed by spring water. The irrigation waters were divided the natural type ditch and the maintained ditch that connect with nearby natural ditch to promote environmentally friendly agriculture. This study was conducted in both sections to support the maintenance of the irrigation water fed by the abundant spring water. A vegetation survey was conducted in September of 2005. The survey collected data on the amount of vegetation cover and the stem lengths of the plant species found in selected locations of the study area. The water depths and the flow velocities were also measured in these locations. As for the growth situation of *S. emersum* and *S. erectum*, the submerged form of *S. emersum* was found in water approximately 15 cm deep with a surface flow velocity of approximately 7 cm/s. This species was characterised by a relatively fast flow and relatively shallow water. The emergent and submerged growth forms of *S. emersum* were found in waters having flow velocities faster than those associated with *S. erectum*. The emergent form of *S. emersum* grew in relatively deep water. *S. emersum* is more capable of adjusting to the conditions of stream habitats than *S. erectum*.

Keywords: *Sparganium*; Flow Velocity; Water Depth; Emergent Growth Form; Submerged Growth Form; Natural Type Ditch; Maintained Ditch

1. INTRODUCTION

[1] has established the "Ministry of Agriculture, Forestry and Fisheries (MAFF) biodiversity strategy" to promote approaches to agriculture that recognise the value of biodiversity, reduce damage to the populations of local birds and other animals and protect agricultural resources. The MAFF is promoting types of environmentally friendly agriculture that can coexist with many living organisms. It is necessary to maintain and restore rice fields, ditch and the habitats of wild flora and fauna.

Spring water areas occur in some parts of the alluvial fans located on the plains in the northern area of the Senboku District in the Yokote basin, Akita Prefecture, Northern Japan. The spring water is primarily used to supply an irrigation water. Species included on the Red List of the [2] and [3] are found in the area, including *Hippuris vulgaris*, *Sparganium erectum*, *Sparganium japonicum*, *Sparganium simplex*, and *Pungitius pungitius* [4]. In particular, *Sparganium* (*S. emersum* and *S. erectum*) has a very extensive distribution in the ditch of Niheishimizu and Ohshimizu sections of the town of Misato. *Sparganium* grows to water area where spring water is abundant, and these breeding seasons are August and September [5]. We consider that *Sparganium* is suitable for growth with the above-mentioned ditch. However, recent years, the habitat of *Sparganium* (*i.e.*, *S. erectum*, *S. emersum* and *S. emetsum*) shows the tendency to decrease according to the influence of the development of the river maintenance [6,7]. In addition, basic information on the life history and habitat characteristics of *Sparganium* is lacking. Moreover, few studies have investigated the differences in distribution between *Sparganium* species (*i.e.*, *S. emersum* and *S. erectum*) found in the same aquatic areas or in neighbouring areas.

In this study, we examined the differences in growth situation between different species *Sparganium* (*S. emersum* and *S. erectum*) by comparing the state of the vegetation and the growth environment (water depth, flow

velocity and the maintenance) of these species in the abundant ditch of spring water.

2. MATERIALS AND METHODS

2.1. Study Site

The study sites were located in a spring water area in the Niheishimizu and Ooshimizu sections of the town of Misato, Akita prefecture, Northern Japan (**Figure 1**).

We investigated areas located upstream (Site 1) and downstream (Site 2) of the weir in the Ooshimizu, upstream (Site 3) and downstream (Site 4) of the weir in the Niheishimizu.

The ditch in the Niheishimizu section is maintained by protecting the banks with stones placed in the channel and was originally created and maintained by a farmland consolidation project in 2003. The bottom of the ditch is lined with sling stone, and *Sparganium* plants which were grown in the neighbourhood have been transplanted to the bottom of the ditch. The ditch in the Ooshimizu section has been left in nearby natural form. For the purposes of this study, Niheishimizu was referred as to be a maintained ditch, and Ooshimizu was referred as to be a natural type ditch.

2.2. Sampling and Identification Methods

The investigation was conducted during September of 2005. The vegetation was surveyed using a quadrant frame (50 × 50 cm^2) in each section. The numbers of quadrant frames were 15, 23 in upstream (Site 1) and downstream (Site 2) of the weir in the Ooshimizu, and were 18, 26 in upstream (Site 3) and downstream (Site 4) of the weir in the Niheishimizu. The amount of vegetation cover for each plant species summed the cover of a quadrant for these. The stem length was measured in same quadrant in which vegetation cover was recorded. The stem length included the above-ground portion of the plant in the central of quadrant frame and the submerged portion of the plants in the stream area was included in this measurement. The flow velocity (surface and bottom), the water depth and the vegetation cover were measured at the same time. The flow velocity was measured with a KENEK VP-3000 three-dimensional electromagnetic current meter. The surface measured approximately 3cm under water surface and the bottom measured approximately 1 cm above the stream bed. The following diagnostic characteristics were used to identify *Sparganium* species: *S. erectum* has a divided scape and 3 or more branches, and the upper part of the seed extends above the dome; *S. emersum* has an undivided scape and 4 or more staminate heads, and the pistillate heads above the second are axillary. Moreover, as for S.*erectum*, the dorsal crest of the leaf develops, and the section is triangular. The leaf is 7 - 20 mm in width. As

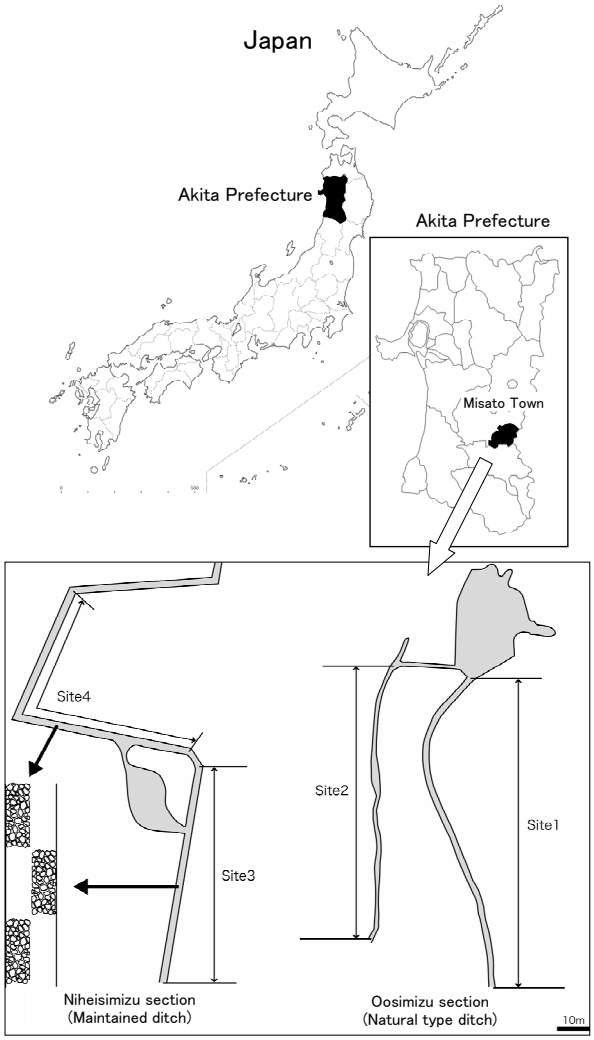

Figure 1. Study site.

for *S. emersum*, the emerged leaf is 5 - 16 mm in width, dorsal crest develops a little. The submerged leaf is 6 - 9 mm in width, the dorsal crest is not remarkable [5].

3. RESULTS

3.1. Vegetation Coverage

Upstream of the weir in the maintained ditch, *S. emersum* and *S. erectum* covered areas of 2.58 m^2 and 0.94 m^2, respectively. Their coverage downstream of the weir were 1.83 m^2 and 3.7 m^2, respectively, and *Typha latifolia* covered 0.35 m^2 downstream of the weir. In the natural type ditch, *S. emersum* covered 2.64 m^2 upstream of the weir, and *S. emersum* and *S. erectum* covered 1.46 m^2 and 1.12 m^2, respectively, downstream of the weir (**Table 1**).

3.2. Flow Velocity and Water Depth

The flow velocity was the highest upstream of the weir

Table 1. The vegetation cover areas (m^2) of aquatic botany founded in the investigation ground.

Species	Maintained ditch Niheishimizu section		Natural type ditch Ooshimizu section	
	Upstream of the weir	Downstream of the weir	Upstream of the weir	Downstream of the weir
Sparganium emersum	2.58	1.83	2.64	1.46
Sparganium erectum	0.94	3.70	-	1.12
Typha latifolia	-	0.35	-	-
Total	3.52	5.88	2.64	2.58

in the natural type ditch. The flow velocity was successively lower downstream of the weir in the natural type ditch, downstream of the weir in the maintained ditch and upstream of the weir in the maintained ditch. The water was the deepest upstream of the weir in the maintained ditch. The water depth was found to be successively reduced downstream of the weir in the maintained ditch, downstream of the weir in the natural type ditch and upstream of the weir in the natural type ditch.

The relative coverage of the emergent and submerged growth forms of the plants differed among the sampling sites. The emergent form showed a coverage of 100% upstream of the weir in the maintained ditch, and the submerged form showed a coverage of 100% upstream of the weir in the natural type ditch. Overall, the relative abundance of the submerged form increased with increasing flow velocity and decreasing water depth (**Figure 2**).

3.3. The Relative amounts of Vegetation Cover according to Species, Stem-Length Class and Growth Form

The emergent form of *S. emersum* was found both upstream and downstream of the weir in the maintained ditch. The relative amount of vegetation cover represented by the short stem lengths was higher in these locations than in the location downstream of the weir in the natural type ditch. The submerged growth form was found upstream of the weir in the natural type ditch, and both growth forms were found downstream of the weir in the natural type ditch. In the natural type ditch, the relative coverage of the shortest stem-length class was higher upstream of the weir than downstream of the weir.

The emergent form of *S. erectum* upstream of the weir in the maintained ditch showed the highest relative amount of vegetation cover in the stem-length class of 1.5 - 2.0 m. Both growth forms of this species were found downstream of the weir in the maintained ditch and downstream of the weir in the natural type ditch. *S. erectum* was not found upstream of the weir in the natural type ditch (**Figure 3**).

3.4. The Growth Environment (Flow Velocity and Water Depth) of the Species and Growth Forms of *Sparganium*

The surface and bottom flow velocities were nearly equal in each case studied. The submerged form of *S. emersum* was found in the fastest-flowing, shallowest water. The emergent form of *S. erectum* was found in even slower and even deeper water. The emergent form of *S. emersum* was found in water having flow velocities similar to those associated with the submerged form of *S. erectum* and in water deeper than that associated with the other growth forms of both species (**Figure 4**).

4. DISCUSSION

The Growth Situation of *Sparganium* in Each Sampling Location

The emergent form of *S. erectum* was only found upstream of the weir in the maintained ditch. The relative vegetation cover was the highest for the stem-length class of 1.5 - 2.0 m. Both growth forms of *S. erectum* were found downstream of the weir in the maintained ditch and downstream of the weir in the natural type ditch. *S. erectum* was not found upstream of the weir in the natural type ditch (**Figure 3**).

S. erectum grows in lotic and lentic environments. Many species of this genus grow as a submerged form in running water [7]. However, the emergent of *S. erectum* occur commonly at the margins of low- and medium-energy river systems across the northern temperature zone [8]. *S. erectum* grows densely in gradually flowing waters that have a flow velocity of less than 5 cm/s, it is rarely found in rapidly flowing waters that have a velocity of 5 cm/s or more. Indeed, it has been reported to grow tall in a deep, gently flowing stream [9].

Upstream and downstream of the weir in the maintained ditch, an extremely gradual flow of less than 5 cm/s was recorded, and the water depth was 30 cm or greater. Downstream of the weir in the natural type ditch, the flow velocity exceeded 5 cm/s, and the water depth was (16.73 ± 0.34) cm, a relatively low value.

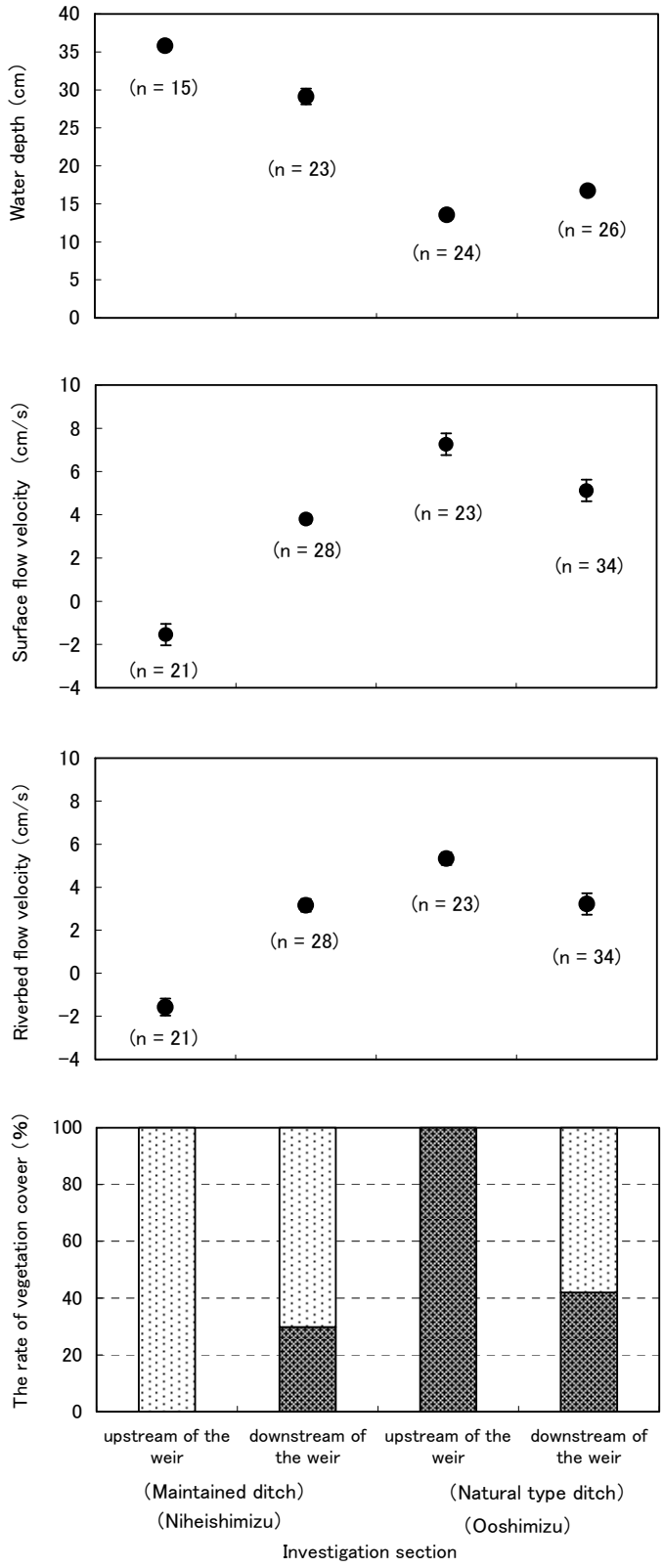

Figure 2. The rate of vegetation cover on each life form of aquatic macropyhtes (Total values), flow velocity and water depth in each investigation section. ※The vertical bars indicate a standard error. N shows the number of measurement.

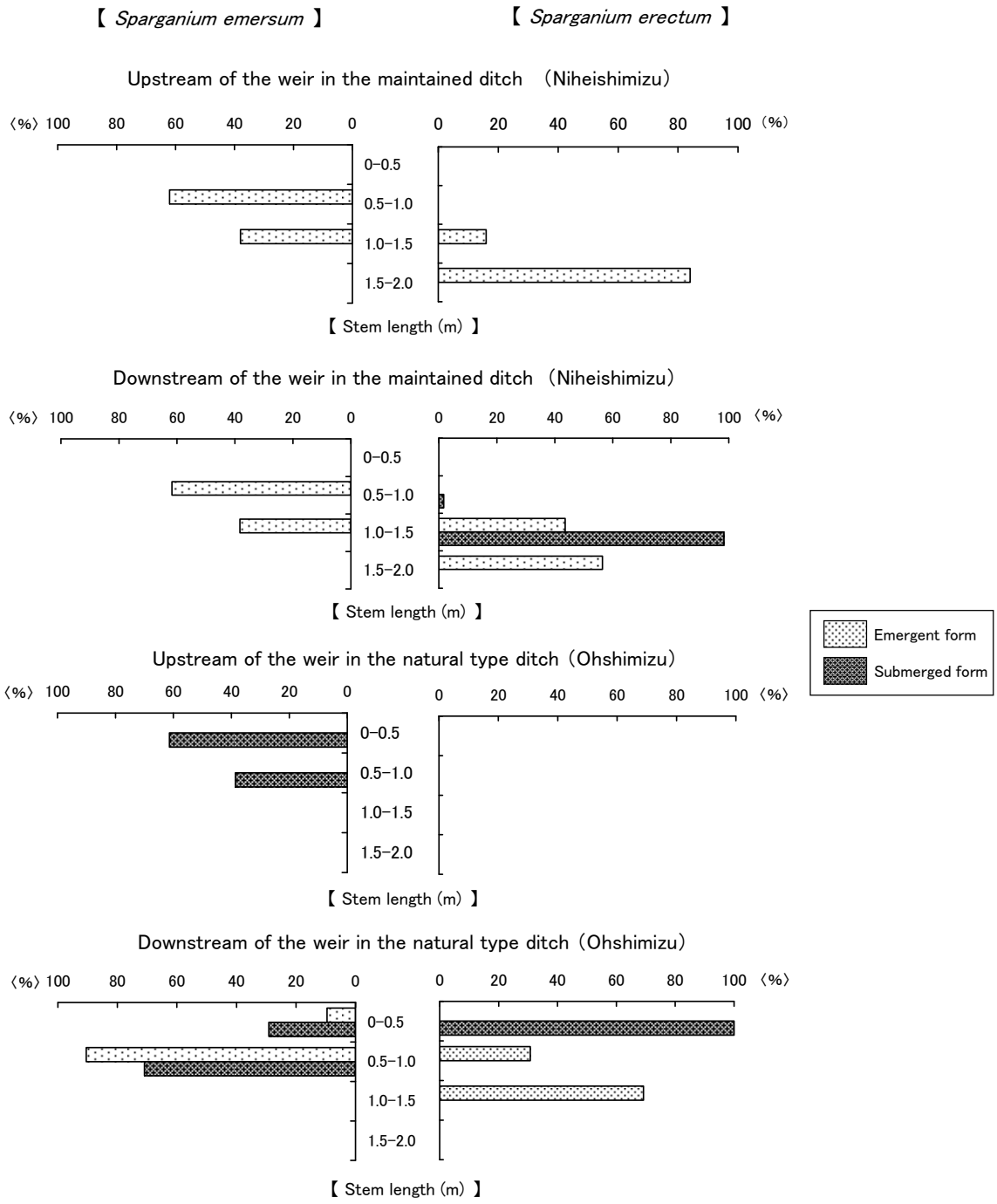

Figure 3. The relative amounts of vegetation cover of stem length class of life form on *Sparganium* (*S. emersum*, *S. erectum*) in investigation section (%).

We hypothesised that the emergent form of *S. erectum* grows by extending its stems and expanding its distribution in waters whose flow velocity is less than 5 cm/s and whose depth exceeds 30 cm. If the flow velocity exceeds 5 cm/s and the water depth is approximately 15 cm or greater, the plant must develop a submerged growth form. Upstream of the weir in the natural type ditch, only the submerged form of *S. emersum* was found. The relative vegetation cover was highest for the shortest stem-length class of 0 - 0.5 m.

S. emersum is dominated in waters where a fast flow and disturbance are strong, and adapted by the submerged type as these influences strengthens in comparison to *S. erectum* [10]. The submerged form of *S. emersum* grows in running waters. It grows densely at bottom flow velocities (measured approximately 1 cm above the

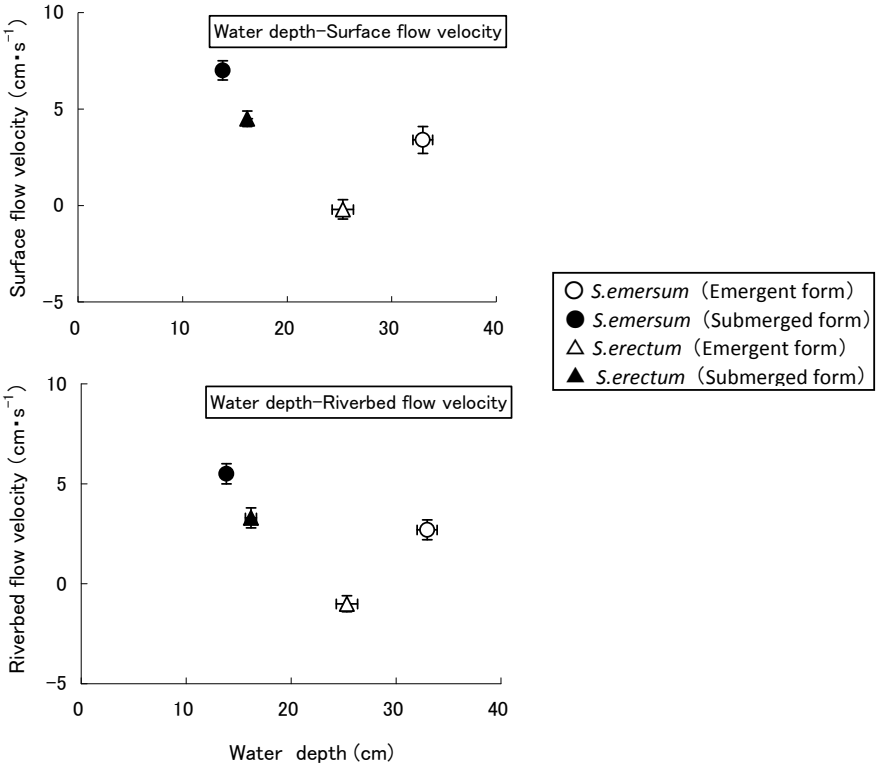

Figure 4. The relationship flow velocity, water depth and stem length in habitat of *Sparganium* (*S. emersum*, *S. erectum*). ※The vertical and horizontal bars indicate a standard error.

stream bed) of (3.9 ± 0.4) cm/s to (5.9 ± 2.4) cm/s [11]. In this study, the stream bed flow velocity upstream of the weir in the natural type ditch was (5.3 ± 0.3) cm/s, and the water depth was (13.6 ± 0.15) cm (**Figure 2**).

We hypothesised that the submerged form of *S. emersum* is suitable for these environmental conditions because the plant controls its growth as the flow velocity increases and the depth decreases. Although the stems of *S. emersum* tend to be shorter than those of *S. erectum*, the short stem might enhance the capability to resist strong drag in fast flow.

As other study cases, *S. erectum* grows in waters where the flow is comparatively gradual and sand and silt accumulate [12]. *S. emersum* grows well in a gradual flow, mud, and argillaceous soil [13], and it also grows in sandy, muddy sediment with constant water flow velocities and is found in eutrophic conditions [14]. To clarify the factors affecting the growth of the two species, future research on *Sparganium* habitats should include investigations of the water quality and the soil substrate.

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