Nat. Hist. Res., Vol. 7 No. 2: 101–105, March 2003

Chara Species that Emerged from 40-year-old Sediments from Lake Teganuma, Central Japan

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Abstract To assess the availability of older lake sediments for restoring wetland vegetation, we conducted a germination test using sediments of Lake Teganuma, Chiba, Japan, that were deposited before 1958, which contained the seeds of some aquatic plants. After one year, 29 plants emerged: one was identified as *Chara globularis* Thuiller and the other 28 as *Chara braunii* Gmelin, which are listed as 'critically endangered'. This study showed that older, lower sediments are useful for restoring wetland vegetation.

Keywords: buried seed, lake sediments, Characeae, aquatic plant, conservation, wetland vegetation.

Introduction

At one time, Lake Teganuma, in Chiba, central Japan, harbored many kinds of aquatic plants (Otaki, 1975). Land reclamation in 1958–1965, and the ensuing water pollution from the inflow of household and agricultural drainage, decreased aquatic plant numbers rapidly, and all submerged and floating-leaved plants became extinct by 1973 (Hosoya, 1993). Near Lake Teganuma, some aquatic plants including the endangered species *Potamogeton dentatus* Hagstr. emerged in a ditch that was excavated in 1990 (Saito, 1991) and in an artificial pond in 1992 (Chiba Prefectural Government—Nature Conservation Division, 1999). Since this construction was thought to have removed landfill that had been used to reclaim Lake Teganuma, these plants probably germinated from seeds that were buried in the lake sediments before reclamation.

Sedimentary environments and diagenesis after deposition have great effects on the distribution and preservation of any seeds and fruit in the sediments (Momohara and Minaki, 1988; Momohara and Yoshikawa, 1997). Momohara *et al.* (2001) stated that it is comparatively easy for aquatic plant seeds to remain viable for a long time, because they make seed banks in the anoxic soils beneath the water bottom. They also touched on the higher genetic diversity of such buried seeds, hinting that seeds buried in old sediments are useful for conserving aquatic plants.

Although restoration of wetland vegetation using buried seeds has been attempted by spreading the surface sediments of marshes (Welling *et al.*, 1988; Imahashi and Washitani, 1996) and lake bottoms (McFarland and Rogers, 1998; Omura *et al.*, 1999), all of these attempts used seeds that were buried only recently. In the case of Lake Teganuma, where the vegetation was destroyed decades ago, restoration necessitates the use of sediments that were laid down before the decrease in aquatic plants. Momohara *et al.* (2001) ascertained that buried seeds are not distributed uniformly in sediments, and recommended checking the species composition of seeds and their condition of preservation before spreading sediments.

To assess the availability of older lake sediments for restoring wetland vegetation, we conducted a germination test using Lake Teganuma sediments that were deposited before 1958, which contained the seeds of some aquatic plants.

Materials and Method

Lacustrine sediments from the north side of Lake Teganuma, Chiba, central Japan, (35°51′9″N, 140°3′26″E) were used. Recent construction had exposed these sediments. Momohara *et al.* (2001) reported that these sediments were composed of silt deposited before 1958 (Fig. 1), and obtained the seeds of 19 aquatic plant species by sieving the sediments with a 0.5-mm mesh sieve (Table 1). Of these, the seeds of three species retained embryos or endosperm.

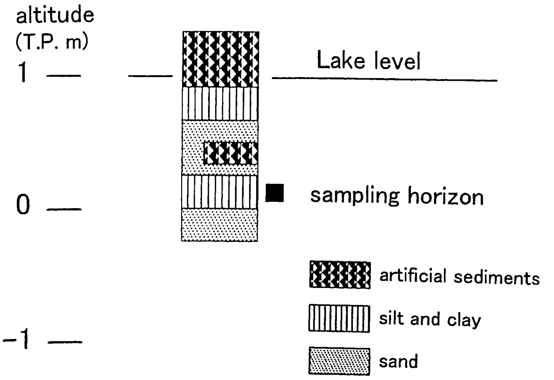

Fig. 1. Geological profile of sampling point. Data were extracted from Momohara *et al.* (2001).

Fresh sediments were collected on June 29, 2000, just after construction. Soon after collecting, they were spread to a thickness of 100 mm in three aquariums made of FRP (W 800×L 1700×D 400 mm) in an outdoor nursery at Tsukuba Botanical Garden, National Science Museum, Japan. The depth of the water was kept at 300 mm year round. High water temperatures in summer were prevented by circulating the well water. Light microscope observations to identify species were carried out with an SZX12 microscope (Olympus, Tokyo, Japan).

Results

More than a year after the experiment began, many Characeae (Charophyceae)

Table 1. Seeds buried in the sediments from Lake Teganuma.

Species	Number of seeds
submerged and floating-leaved plants	
Nitella sp.	50
Ruppia rostellata Koch	abundant
Potamogeton malaianus Miq. type	247
Potamogeton dentatus Hagstr.-*P. maackianus* A. Benn type	910
Potamogeton sp. A	6
Potamogeton sp. B	1
Najas marina L.	8
Najas graminea Del.	3(2)*
Vallisneria asiatica Miki	48(42)
Vallisneria denseserrulata (Makino) Makino	261(250)
Hydrilla verticillata (L. *f.*) Casp.	4
Ceratophyllum demersum L.	1
Nymphoides indica (L.) O. Kuntze	168
Nymphoides peltata (Gmel.) O. Kuntze	13
emergent and marsh plants	
Carex sp.	33
Scirpus juncoides Roxb. type	6
Scirpus triqueter L. type	29
Myriophyllum sp.	927
Triadenum japonicum (Blume) Makino	1

* Numbers in parenthesis indicate number of seeds with endosperm and/or embryo.
Data were extracted from Momohara *et al.* (2001).

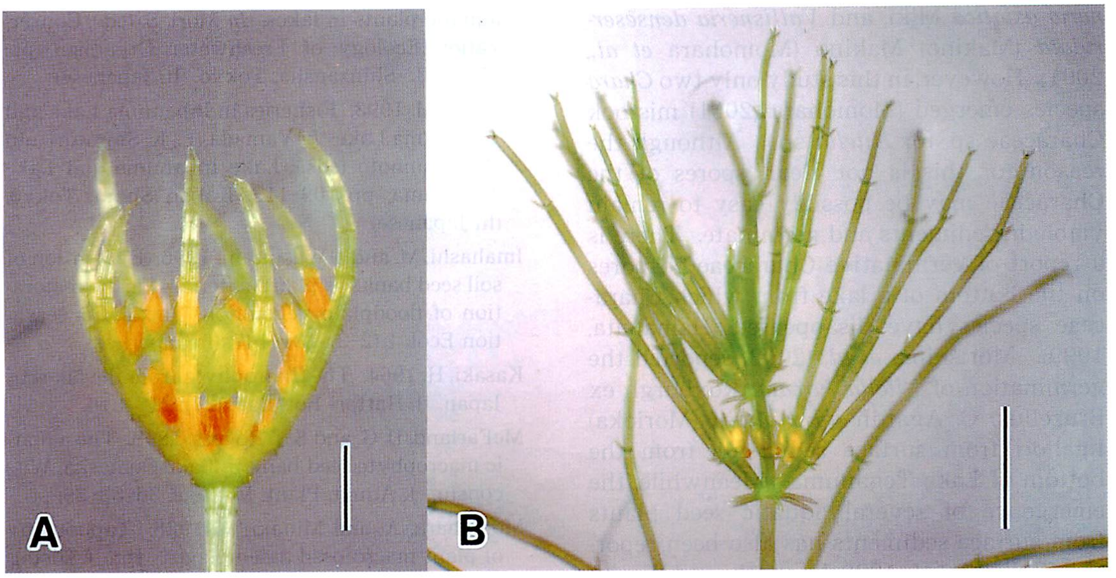

Fig. 2. Characeae plants that emerged from the lake sediment. A, *Chara globularis* Thuiller, scale bar=1 mm; B, *C. braunii* Gmelin, scale bar=3 mm.

plants emerged from the sediments in Oct. 2001; altogether, 29 plants grew in the three aquariums. Parts of these plants were transplanted to an indoor aquarium, and after cultivation the reproductive organs were observed and identified; one plant was identified as *Chara globularis* Thuiller f. *globularis* and the other 28 as *C. braunii* Gmelin (*C. braunii* f. *braunii*), based on the vegetative and gametangial morphology, following Wood and Imahori (1965). *C. globularis* f. *globularis* (Fig. 2-A) is a cosmopolitan species that was once distributed from northern to central Japan. However, it now occurs in only eight among Japanese lakes (Environment Agency of Japan, 2000). Although *C. braunii* (Fig. 2-B) is also a cosmopolitan species that is distributed throughout Japan, its habitat is decreasing. Both species are listed as 'critically endangered' (Environment Agency of Japan, 2000) and are in danger of extinction in the wild. Because Kasaki (1964) reported that *C. globularis* Thuiller var. *globularis* and *C. braunii* Gmelin were found in Lake Teganuma and then Nozaki *et al.* (1995) did not found these species in Lake Teganuma, regeneration of two extinct species in Lake Teganuma was achieved in this study.

Discussion

Two pieces of vital information were provided by the emergence of *Chara* species from lacustrine sediments that were deposited decades ago. First, our results demonstrated the regeneration of aquatic plants using sediments of known origin. As the restoration of wetland vegetation using buried seeds has to date been carried out mainly by spreading surface sediments (Welling *et al.*, 1988; Imahashi and Washitani, 1996; McFarland and Rogers, 1998; Omura *et al.*, 1999), the origin of any plants that emerged was not clear. The spread of sediments containing seeds that are not derived from the native vegetation might disrupt the existing vegetation.

Second, we showed that older, lower sediments are useful for conservation. Even if the original vegetation has disappeared as a consequence of human activities, efficient restoration of vegetation might be possible using a procedure such as ours, after first investigating the species composition and condition of preservation of seeds in the lower sediments before spreading.

The sediments that we used were reported to contain seeds with embryos or endosperm of three species: *Najas graminea* Del., *Vallis-*

neria asiatica Miki, and *Vallisneria denseserrulata* (Makino) Makino (Momohara *et al.*, 2001). However, in this study only two *Chara* species emerged (Momohara (2001) mistook Characeae sp. for *Nitella* sp.). Although the reason for this is not clear, spores of the Characeae may be possibly easy to remain viable in sediments and germinate. There is a report of germinative Characeae oospores on the bottom of a lake from which Characeae species have disappeared (Hamahata, 1999). Morishima *et al.* (2002) reported the germination of *Nitella furcata* (Roxburgh ex Bruzelius) C. Agardh var. *fallosa* (Morioka) Imahori from surface sediments from the bottom of Lake Teganuma. Meanwhile, the emergence of several aquatic seed plants from surface sediments has also been reported (Welling *et al.*, 1988; Imahashi and Washitani, 1996; McFarland and Rogers, 1998; Chiba Prefectural Government—Nature Conservation Division, 1999; Omura *et al.*, 1999). These works suggest the possibility of regenerating other aquatic seed plants from older sediments, as well as *Chara* species, as occurred in our study. Further studies on the volume of sediments, method of incubation, and choice of method according to seed composition are necessary, to achieve reliable restoration of wetland vegetation from older, lower sediments.

Acknowledgments

We are grateful to Prof. Kozai, Chiba University, for helpful comment. Financial support of this study was provided in part by WWF Japan, Futaba Electronics Memorial Foundation, and Foundation of Rivers and Watershed Environment Management.

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(Accepted 4 March 2003)

40年前の手賀沼湖底堆積物から出現したシャジクモ属植物

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水辺植生の再生における古い年代の湖底堆積物の有効性を評価するために，1958 年以前に堆積したと推定されており，埋土種子相も調査されている堆積物のまきだしによる発芽試験を行った．一年以上が経過した後，複数の植物が出現し，1 個体がカタシャジクモ *Chara globularis* Thuiller, 28 個体がシャジクモ *Chara braunii* Gmelin と同定された．いずれも，絶滅危惧 I 類とされている．本研究によって，古い，かつ下層の堆積物が水辺植生の再生に有効であることが示された．