

# Alien Aquatic Plants Naturalized in Japan: History and Present Status

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## Abstract

Introduction of alien aquatic plants started in the Meiji Era (late 1800s) and some of them have been naturalized and caused serious weed problems in Japan. *Eichhornia crassipes*, *Elodea nuttallii*, *Egeria densa* and *Pistia stratiotes* have proven to be typical noxious aquatic weeds. The history of such invasive alien aquatic plants is briefly reviewed. Recently, more and more alien aquatic plants have been introduced due to a boom in aquarium and water gardening. Some of the newly introduced alien aquatic plants have begun to spread quickly. To date over 40 species have escaped and become naturalized in Japan. They threaten the biodiversity of native aquatic plants in various ways. The social backgrounds of the spread of alien aquatic plants are surveyed and the need for social education as well as legal regulation to discourage destructive activities are emphasized.

**Key words:** alien aquatic plants, aquarium plants, naturalization, vegetative propagation, weed problems

## 1. Introduction

Some alien aquatic plants introduced from their native localities have spread explosively and caused serious socio-economic problems in various parts of the world as exemplified, for example, by *Eichhornia crassipes* (water hyacinth) and *Salvinia molesta* (= *S. auriculata*?) (Sculthorpe, 1967; Gopal & Sharma, 1981; Cook, 1990). They have also had serious impacts on regional biodiversity and functions of freshwater ecosystems. Cook (1985) enumerated many species which have enlarged their distribution area as alien aquatic plants worldwide, although the documentation on the spread of aquatic plants into new areas was assumed to be unsatisfactory. Generally speaking, means of vegetative reproduction are well developed in aquatic plants and, once introduced, they can propagate vigorously in suitable habitats. The uniformity and mildness of aquatic environments as compared with terrestrial ones are also factors which enable the spread of many alien aquatic plants over a wide range.

In Japan, alien aquatic plants have been introduced since the Meiji Era (late 1800s). For example, *Eichhornia crassipes* was introduced as an ornamental plant in 1884 or earlier (Kadono, 1996a). Similarly, *Myriophyllum aquaticum* (formerly *M. brasiliense*; a

species of parrot feather), *Cabomba caroliniana*, and *Iris pseudoacorus* were among the alien aquatic plants which were introduced as decorative plants around 1900 (Ohtaki & Ishido, 1980). *Egeria densa* (formerly often described as *Elodea densa*) was introduced in the 1920s as an experimental botanical material. Actually several scientific papers have been published on its physiology and cytology in Japanese journals since the 1930s. These plants escaped into the wild and have become naturalized, spreading their distribution. Some of them are truly invasive weeds and have become serious pests in many places (Kadono, 1996b, 2001).

In the past few decades, more and more alien aquatic plants have been newly introduced and commercially sold by various routes according to booming demand for aquarium and water gardening. Some of these have escaped into the wild and started to spread rapidly (Kadono, 2004). Their vigorous spread has threatened the biodiversity of native freshwater ecosystems. Although much money has been spent to control alien aquatic plant infestations, in some cases, eradication of such plants has proven to be difficult.

In this paper, the history of representative alien aquatic plants in Japan is briefly reviewed and the present status and future scope are discussed.

## 2. Weed Problems Caused by Alien Aquatic Plants: a Historical Review

In this section some representative examples of the noxious alien aquatic plants which have caused serious weed problems in the past in Japan are described.

### 2.1 *Eichhornia crassipes* (water hyacinth)

*Eichhornia crassipes*, native to South America, is a free-floating aquatic plant and well known as the most troublesome aquatic weed in tropical and subtropical regions of the world (Gopal & Sharma, 1981). *Eichhornia crassipes* has been introduced to many countries as an ornamental plant for its beautiful flowers. However, once escaped, it spreads vigorously by vegetative means and chokes the surface of waters such as rivers, lakes and reservoirs in a short time.

In Japan, in so far as records are available, it was introduced via North America in 1884 (early Meiji Era) as an ornamental plant (Kadono, 1996a). After that it escaped into natural waters and had already spread to rice fields and creeks in southwestern Japan by the early 1900s (Ueki *et al.*, 1976). According to some fragmentary information, the plant seemed common in the creeks of Kyushu at that time. Hakushu Kitahara, a poet who was born in Yanagawa, an area with many creeks in Kyushu, described the scenery of the creeks choked by *E. crassipes* in a poem in the 1920s. An explosive expansion of *E. crassipes* was reported thereafter in some waters in Kyushu, but it was since the 1960s that the weed problems caused by *E. crassipes* have attracted social attention. The development of urban areas and industrialization in Japan has accelerated eutrophication of water in many lakes, rivers and ponds. As a result *E. crassipes* has spread explosively in many eutrophicated waters in southwestern to central Japan.

The dense floating mats of *E. crassipes* cover the whole surface of waters and cause some problems like the choking of irrigation and drainage ditches, interference with boating and fishing, unpleasant odors and flavors, water enrichment by dead plants in winter, and so on (Ueki *et al.*, 1976). Because of complete coverage of the water surface by pure stands of *E. crassipes*, native aquatic plants have lost their niche and been expelled. Depletion of dissolved oxygen in the water occurs under the dense mats of the plants and its adverse influence on ecosystem function is serious. Although much money has been spent to control the *E. crassipes* infestation, it is still one of the most troublesome alien aquatic weeds in Japan.

### 2.2 *Elodea nuttallii* and *Egeria densa*

*Elodea nuttallii* is a submerged plant native to North America. It was found in the northern part of Lake Biwa, the largest lake in Japan, for the first time in 1961 (at that time it was identified as *Elodea occidentalis*; Ikusima & Kabaya, 1965). Within several years the plants spread over the whole area of

the lake and became the most dominant plant in the lake. Almost all the littoral regions were occupied by the plant, which developed into dense pure stands at 2-5 m depth (Ikusima, 1984). At the same time its distribution expanded into other waters over wide areas of Japan. It is said that fragments of the plant were transported together with the fry of *Plecoglossus altivelis* (Ayu) from Lake Biwa to the rivers of various regions in Japan (Ikusima, 1980). Infestations occurred also in some other lakes, e.g. Lake Oze-numa (Kurita & Minemura, 1985a; Nohara, 1988) and Lake Haruna (Kurita & Minemura, 1985b). Because of the explosive expansion of *E. nuttallii* plants, the native flora of the lakes has faced a crisis of extinction.

*Elodea nuttallii* of North American origin can tolerate cool water, so its distribution has now expanded throughout Japan including Hokkaido. It also grows well in spring-fed clear, oligotrophic water. There it competes with *Ranunculus nipponicus* and other species adapted to spring-fed water and threatens the unique ecosystems of Japan.

*Egeria densa* (formerly often described as *Elodea densa*) is also a submerged plant native to South America. Since its introduction occurred in the 1920s, it has longer history of naturalization in Japan than *Elodea nuttallii*. Kadono (1994) presumed that its naturalization occurred at the latest in the 1940s, based on herbal specimens collected in 1941 in Yamaguchi, southwestern Japan. Most probably the plant started to expand its distribution in southwestern Japan at that time. However, few reports are available about its exact status till the 1980s. However, in 1980, it underwent an explosive expansion in Lake Biwa and became the dominant plant in place of *Elodea nuttallii*. The event attracted social attention as a serious weed problem because its dense communities hindered ship navigation and fisheries in the lake. Of course its effect on the ecosystem of the lake itself was considered serious. Because *Egeria densa* as well as *Elodea nuttallii* are evergreen plants, they have a competitive advantage over the native aquatic plants. They cover the bottom of the lake from winter to spring and hinder the sprouting and early growth of native plants which are dormant in winter. Actually the biomass of the native plants declined drastically after the invasion of *Elodea nuttallii* and *Egeria densa* (Ikusima, 1991).

In the 1980s, *Egeria densa* became the second most common aquatic plant species following *Potamogeton crispus* in the rivers and streams of southwestern Japan (Kadono, 1988). *Egeria densa* was shown to grow well above 15°C (Haramoto & Ikusima, 1988) and has extended its distribution mainly in central to southwestern Japan, but even in northern Japan it has invaded some waters under the influence of hot springs or other kinds of warm discharge. Recently, dominance of *E. densa* communities has been observed in many rivers. This may be associated with

the increase of water temperature caused by global warming and constant supply of nutrients.

Although the reason is still not known, populations of both *Elodea nuttallii* and *Egeria densa* have been observed declining or completely disappearing after their explosive expansion. A similar case is well known regarding *Elodea canadensis* in the late 1800s in Europe (Arber, 1920). As to the causes of the decline in the populations, some hypotheses have been proposed: e.g., genetic explanations such as the loss of viability owing to lack of sexual reproduction; and depletion of some nutrients (for review, see Hutchinson, 1975). Kadono *et al.* (1997) suggested vulnerability to attacks by pathogens or fungi because of genetic uniformity of the population. The involvement of such organisms as a possible cause of the decline of populations should also be explored in future studies.

In case of Lake Biwa, the biomass of *Elodea nuttallii* and *Egeria densa* decreased as compared with that in the 1970s and 1980s and the populations of representative native species have recovered well (Hamabata, 1991). However, the biomasses of both species are still considerable. Large masses of floating mats of *E. nuttallii* detach from the bottom and drift up to the lake shores every year.

### 2.3 *Pistia stratiotes* (water lettuce)

*Pistia stratiotes* (Fig.1) is a free-floating plant which is now widely distributed in tropical and sub-tropical regions of the world. The species was



Fig. 1 *Pistia stratiotes* invasion in a *Salvinia natans* community. (Kakogawa City, Hyogo Pref.)



Fig. 2 *Pistia stratiotes* on sale in a gardening shop. The attached label says that the plant is a 'biotope plant' useful for water purification. (Kobe City, Hyogo Pref.)

recorded as early as the 1930s in the Okinawa Islands, the southernmost islands of Japan (Makino & Nemoto, 1931), but its naturalization in other regions was not reported till the 1990s. Since the early 1990s an explosive expansion of *P. stratiotes* has been reported in many waters mainly in southwestern Japan (e.g., Shimoda, 1982; Kamiaka, 1999; Mochida & Miura, 2001). Kadono (2001) suggested that the northward shift of the distributional areas of the species may be associated with increasing temperatures due to global warming.

The rate of propagation of *P. stratiotes* is comparable to that of *Eichhornia crassipes*. In the case that *P. stratiotes* and *E. crassipes* flourish together in the same water, *P. stratiotes* is more dominant and difficult to control than *E. crassipes*.

*Pistia stratiotes* can not survive Japanese winters exposed and its dominance may be only for one year, although a case of over-wintering in ponds with warm water discharge has been reported (Kamiya & Kunii, 1995). Nevertheless, new populations are found in other waters the following year. The reason is that *P. stratiotes* has become a popular and common plant for cultivation in private ponds, aquaria, or 'biotopes' and is available at low prices in many gardening shops and even at so-called 'home centers' (Fig. 2). The plants are often thrown away when they cover the whole water surface by clonal growth under cultivation. They become a source of vigorous spread in suitable habitats. Successful seed production and over-wintering by seeds as reported by Yamamoto and Fujii (1996) may be a potential menace which makes it more difficult to eradicate the populations.

### 2.4 Other species naturalized for a long time in Japan

In addition to the above-mentioned species, some other alien species have established themselves in Japanese waters for a long time. *Myriophyllum aquaticum* (= *M. brasiliense*), a parrot feather, was introduced as a decorative plant in the 1910s. No accurate history of its naturalization or expansion is known but it has now become a nuisance plant covering whole water surfaces in some places (Fig.3).



Fig. 3 *Myriophyllum aquaticum* invading a community of *Nuphar japonica*. The *Nuphar japonica* plants were threatened by *M. aquaticum*. (Akou City, Hyogo Pref.)

*Cabomba caroliniana* is a popular aquarium plant. Its first record in Japan was in 1929 (Masamune, 1931). Though it has not caused such serious weed problems in our country, it is now distributed all across Japan. *Iris pseudacorus* was introduced from Europe in the 1890s (Ohtaki & Ishido, 1980). At first it was a horticultural plant but now it has become naturalized in many lakes, ponds and rivers throughout Japan.

In Table 1, alien aquatic plants which have been reported to occur in the wild are listed, including recently naturalized ones.

### 3. The Recent Increase in Newly Introduced Alien Aquatic Plants: Its Background and Present Status

Recently more and more alien aquatic plants have been introduced into Japan and sold in aquarium shops and through the Internet. The cultivation of aquatic plants in aquaria and in the water gardening ponds is in fashion and has many semi-professional and amateur enthusiasts. Now anyone can get alien aquatic plants easily by various means. This is why

**Table 1** A list of alien aquatic plants naturalized in Japan\*.

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1. Widespread and completely naturalized species  
*Eichhornia crassipes* (Mart.) Solms-Laub.  
*Egeria densa* Planch.  
*Elodea nuttallii* (Planch.) St. John  
*Iris pseudacorus* L.  
*Paspalum distichum* L. var. *distichum*  
*Paspalum distichum* L. var. *indutum* Shinnars  
*Spirodela punctata* (G.F.W.) Thompson  
*Wolffia globosa* (Roxb.) Hartog & Plas  
*Cabomba caroliniana* A.Gray  
*Nasturtium officinale* R. Br.  
*Myriophyllum aquaticum* (Velloso) Verdc.  
*Nymphaea* spp. (various cultivars and unidentified species are included)
  2. Species with limited distribution  
*Sagittaria graminea* Michx.  
*Vallisneria gigantea* Graebn.  
*Heteranthera limosa* (Sw.) Willd.  
*Bacopa rotundifolia* (Michx.) Wettst.  
*Lemna gibba* L.  
*Trapa bispinosa* Roxb.  
*Utricularia gibba* L.  
*Utricularia inflata* Walter
  3. Species which have increased rapidly in recent years  
*Azolla* spp. (Several species and hybrids were introduced in rice fields to feed ducks in anti-herbicide agriculture)  
*Pistia stratiotes* L.  
*Alternanthera philoxeroides* Griesb.  
*Veronica anagallis-aquatica* L.  
*Gymnocoronis spilanthoides* DC.  
*Hydrocotyle verticillata* Thunb. var. *triradiata* Fern.  
*Hydrocotyle ranunculoides* L.f.  
*Ludwigia repens* Forster
  4. Species which have been observed in the wild but may be of temporal occurrence  
*Salvinia mollesta* Mitchell  
*Limnobium laevigatum* Heine  
*Eichhornia azurea* (Sw.) Kunth  
*Pontederia cordata* L.  
*Thalia dealbata* Fraser  
*Heteranthera zosterifolia* Mart.  
*Lagarosiphon major* (Ridl.) Moss  
*Hydrocleis nymphoides* Buchen.  
*Neputunia oleracea* Lour.  
*Nymphoides aquatica* (Walt.) O. Kuntze
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\* This list was compiled based on published records and other reliable information on naturalized plants. Some other unidentified alien aquatic species have been reported, including Alismataceae, Poaceae, Cyperaceae, Juncaceae, etc.

more and more new alien aquatic plants are being introduced and circulated.

Some horticultural and landscape planning companies also deal with alien aquatic plants commercially as ‘biotope plants,’ or plants serving as water purifiers. These plants are planted in the construction of ‘biotopes’ and also in a number of public ‘restoration’ works without correct recognition of the concept of restoration. Such cultivated plants become a source of escapees into natural waters. In some cases they are planted intentionally, although some of them are truly invasive.

For example, *Gymnocoronis spilanthoides* (Fig.4), a Senegal tea plant of South American origin, is rapidly expanding its distribution. The flowers of the plant attract many insects including a beautiful butterfly species as pollinators so some amateur entomologists are interested in the plant. It is said that at one time they did plant *G. spilanthoides* in order to collect the butterfly. The species is also commercially dealt with as a ‘water purification plant’ with no such scientific evidence. Once established in the wild, it spreads vigorously throughout the area (Suyama & Fujiwara, 2003). Up to now it has been reported that *G. spilanthoides* occurs from Kyushu to central Japan. Most of the populations have spread from artificially transplanted sites.

*Veronica anagallis-aquatica* of European origin



**Fig. 4** *Gymnocoronis spilanthoides* stand invading a river. In this river the plants spread widely in a few years. (Takatsuki City, Osaka Pref.)



**Fig. 5** *Alternanthera philoxeroides* spreading in the ‘Wando (stagnant pools)’ of the Yodo River. (Osaka City, Osaka Pref.)

has become a very common plant in some areas in southwestern Japan (Tanaka & Noguchi, 1994). It forms large stands especially in habitats disturbed by river construction works. In addition it hybridized with a related native species *Veronica undulata* (Tanaka, 1995), and the populations of *V. undulata* are now endangered due to the spread of *V. anagallis-aquatica* genetically as well as ecologically.

*Alternanthera philoxeroides* (Fig.5), a species of alligator weed, is a notorious aquatic weed around the world (Spencer & Coulson, 1976). Still now, its distribution is rather sporadic but the populations are increasing rapidly around Lake Inba-numa, Chiba Prefecture, central Japan (Sugiyama & Kuramoto, 2004) and in some localities in southwestern Japan.

*Hydrocotyle ranunculoides* (Figs.6 & 7) has invaded the Kikuchi River and its tributaries in Kyushu and shown an explosive expansion (Ito, 2001). Despite efforts to control the weed by local governments, it is again spreading, forming many dense stands in the area. Its growth potential in relation to the nutrient status of water was studied and its invasiveness was predicted (Hayashida *et al.*, 2003). It is also one of the most invasive alien plants in Japan.

The common features of the invasive alien aquatic plants mentioned so far are strong ability to regenerate from the plant fragments and vigorous vegetative propagation thereafter. Thus, once established, they



**Fig. 6** *Hydrocotyle ranunculoides* community in a tributary of the Kikuchi River. (Shisui Town, Kumamoto Pref.)



**Fig. 7** *Hydrocotyle ranunculoides* elongating using creeping stolons.

spread very quickly in suitable habitats. From the viewpoint of ecological risk assessment we must evaluate such traits accurately.

Many other alien aquatic plants have become naturalized and spread to various degrees. Some are weeds of rice fields and introduced unintentionally. *Heteranthera limosa* and *Bacopa rotundifolia* are among the examples of these. Species which have been cultivated in aquaria and ponds such as *Limnobium laevigatum* and *Hydrocleis nymphoides* have sometimes been observed to grow in the wild. They must have been transplanted intentionally by some aquarium enthusiasts. It is, however, doubtful if they will spread in the future. They may be of temporal occurrence, but some plants which were transplanted to the wild have established themselves. We often encounter alien insectivorous plants which the enthusiasts transplanted to natural wetlands. Figure 8 shows *Utricularia gibba* growing in a species-rich natural pond. Here the species has become one of the dominant species in the flora of the pond. It was an intentional introduction by an enthusiast.

#### 4. Concluding Remarks

More than 300 aquatic plants are available on the market as aquarium plants (Kobayashi, 1995) and many of these are alien. In addition newly introduced alien aquatic plant species are increasing from year to year. Among them, over 40 species have already become naturalized in Japan. In addition to the species listed in Table 1, there are some more species which have not yet been identified. Of course, some of them are limited in distribution and may not be invasive, but we have inadequate knowledge of their ecological traits and suitable habitat conditions. We should assume that many of them may be invasive. Nevertheless, the introduction and circulation of alien aquatic plants have not been regulated legally as of this time.

Besides the hobby of aquarium fans, another big problem is that some alien aquatic plants are planted in nature conservation and restoration projects by administrations and some citizens groups in good will. They think simply that the recovery of 'greenery' is a



Fig. 8 *Utricularia gibba* naturalized in a pond. (Nara City, Nara Pref.)

favorable thing. Such mistaken activities should be stopped as soon as possible. It is necessary to have people understand the importance of the conservation of biodiversity of locally unique nature. We should make all efforts to prevent the escape of alien aquatic plants. To achieve this purpose, both social education to promote the public awareness of the ecological risks of alien plants and legal regulation of alien aquatic plants will be equally important and indispensable.

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