J. Aquat. Plant Manage. 33: 13-19

Identification, Biology and Management of *Elodea canadensis*, Hydrocharitaceae

KATHLEEN H BOWMER[1], S.W.L. JACOBS[2] AND G.R. SAINTY[3]

ABSTRACT

Elodea, Egeria, Hydrilla, and *Lagarosiphon* have been much confused in the literature, mainly because of similarities in appearance and habitat. As well there has been confusion as to the number of species in *Elodea* and their correct names. We provide two keys, the first to help distinguish the genus *Elodea* from its near relatives, and the second to distinguish the species within *Elodea*. The distribution of the species of *Elodea* is described along with their physiology, survival and dispersal. The economic importance and management of the weed species of *Elodea* are discussed and recommendations for control are made.

Key words: *Hydrilla, Egeria, Lagarosiphon*, taxonomy, herbicides.

IDENTIFICATION

Elodea spp., *Egeria densa* Planch., *Hydrilla verticillata* (L.f.) Royle and *Lagarosiphon major* (Ridley) Moss, all belonging to the family Hydrocharitaceae, are submerged perennial species that usually root in mud. They are similar in appearance, and have all been recorded as weedy, although usually not in their country of origin. Early misidentification is reflected in the confusion of common names in the USA. For example *Hydrilla verticillata* is called Florida Elodea, *Egeria densa* is Brazilian Elodea, and *Elodea canadensis* is American Elodea or Canadian Pondweed. *Elodea, Egeria and Hydrilla* have quite different flowers, but vegetatively are very similar. All have herbaceous stems and oblong to linear leaves in whorls of two to eight.

Elodea canadensis (Figure 1) is distinguished from *Hydrilla verticillata* (Figure 2) by the number of leaves in the whorls (usually three in *Elodea*, and four to six in *Hydrilla*) and by lacking the marked leaf serrations and scratchy feel (when handled in the water) of the latter. *Egeria densa* (Figure 3) is distinguished by its larger leaves which are usually in whorls of four or five (sometimes three to eight). It differs from both *Elodea* and *Hydrilla* in its larger, attractive white flowers with three petals (9-12 mm long) and the presence of 'double nodes' (Haramoto and Ikusima 1988).

Lagarosiphon major (Figure 4) is a native of southern Africa and is potentially a serious weed of deep storages. In New Zealand it was first recorded in lakes in 1950, where floating plants blocked intakes to hydro-electric generators. It has also been recorded in Australia, where it is, as yet, not naturalized; and to prevent its spread it has been declared noxious in all States in Australia. *Lagarosiphon major* is distinguished from the other species mentioned here by its recurved leaves spirally arranged around the stem, rather than in whorls.

KEY TO GENERA

1. Leaves spirally arranged around the stem, the tips often recurved; petals subequal to sepals, < 3mm long. ***Lagarosiphon***

1* Leaves in whorls of 3-8, the tips usually not recurved; petals subequal to sepals or very much longer, 1-12 mm long. **2.**

2. Petals 9-12 mm long, much longer than the sepals; leaves usually in whorls of 4-5 (sometimes 3-8). ***Egeria***

2* Petals <5 mm long, much longer than the sepals; leaves usually in whorls of 2-8. **3.**

3. Leaves usually in whorls of 3 (rarely more, sometimes 2); leaf margins minutely serrulate. ***Elodea***

3* Leaves usually in whorls of 4-6 (-8); leaf margins distinctly serrulate. ***Hydrilla***

Elodea is a genus of dioecious or monoecious perennials with submerged leaves and floating flowers. The leaves are mostly whorled and sessile. Inflorescences are unisexual or bisexual, mostly one-flowered. Flowers have two almost equal perianth whorls, each with three membranous segments. Male flowers reach the surface on slender, fragile pedicels. The flowers sometimes detach. The pollen is usually shed directly on the water surface. In *Elodea nuttallii* (Planch.) St. John, the male flower bud becomes detached and free-floating, the flowers open and the pollen is shed as it blows around. Female flowers are floating and attached. The ovaries are one-locular and have three styles. The fruit is capsular and produces one to five seeds.

Historically there has been much confusion in the classification of the species *Elodea*. St John (cited in Cook and Urmi-König 1985) described 17 species. Corell and Corell (1975) recognized four species (*Elodea bifoliata* St John, *E. longivaginata* St. John, *E. canadensis* and *E. nuttallii*) in the United States. However, Cook and Urmi-König (1985), in the latest revision of the genus recognize five species of *Elodea*: *E. canadensis, E. potamogeton* (Bert) Espinosa, *E. bifoliata*, *E. nuttallii* and *E. callitrichoides* Casp., and believe that there are also naturally occurring hybrids between *E. canadensis* and *E.*

[1]CSIRO Division of Water Resources, Griffith, NSW 2680, Australia
[2]Royal Botanic Gardens, Sydney, NSW 2000, Australia
[3]Sainty and Associates, Box 1219, Potts Point, NSW 2011, Australia.
Received for publication November 22, 1993 and in revised form August 8, 1994.

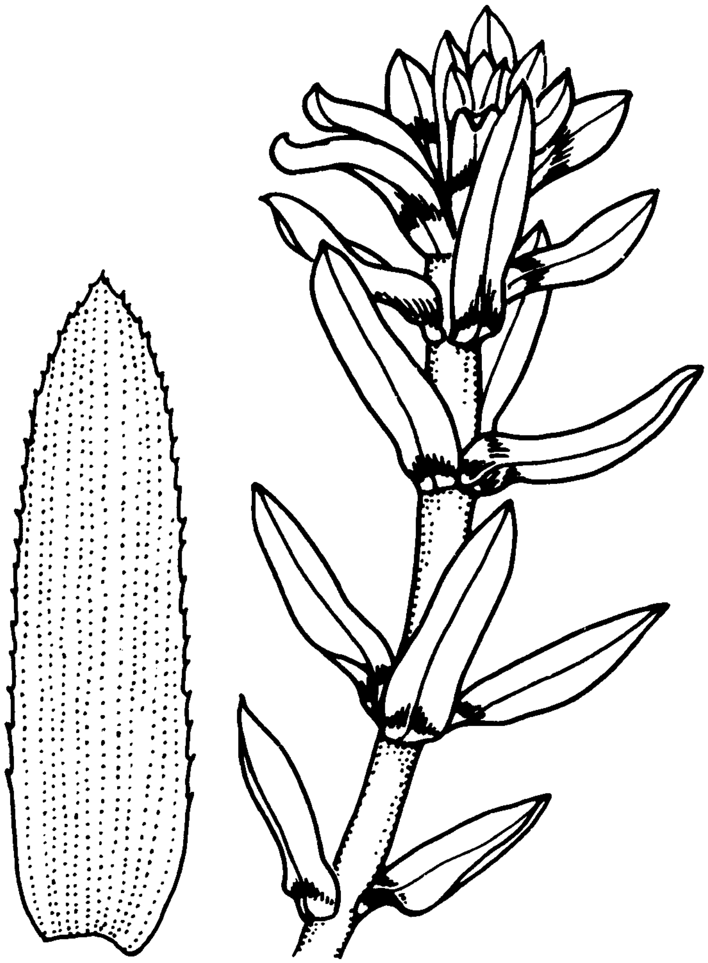

Figure 1. *Elodea canadensis* (×1, leaf ×3) leaves in whorls of three. (Illustration by Christine Payne, from Sainty and Jacobs 1988).

nuttallii. They present three identification keys based on leaf characters, male flowers and female flowers. The key based on leaf characters is reproduced here in simplified form. The characters refer to the larger leaves towards the shoot apex of healthy plants.

1. Majority of leaves 1.75 mm wide or more **2.**
1* Majority of leaves <1.75 mm wide **4.**
2.Towards the stem apex leaves usually overlapping in regular rows and lying along the stem, often oblong or ovate. ***E. canadensis***
2*Towards the stem apex leaves usually not overlapping and somewhat irregular and spreading, usually lanceolate or elliptic to linear. **3.**
3.Usually some nodes with leaves in fours; leaves usually lanceolate to elliptic, rarely parallel-sided, apex usually widely acute to obtuse. ***E. potamogeton***
3*Usually some nodes with leaves in pairs, never in fours; leaves usually linear and mostly parallel-sided, apex acute. ***E. bifoliata***
4. Leaves usually folded along the midrib, somewhat recurved, with undulate margins, rarely more than 10 mm long. ***E. nuttallii***
4* Leaves usually flat, spreading, with straight margins, at least some usually >10 mm long. ***E. callitrichoides***

Of these, only *E. canadensis, E. nuttallii* and *E. bifoliata* grow in North America, all being native to the region.

Mues (1983) investigated the flavonoid pigment patterns of three *Elodea* species and found them reliable and stable indicators for populations sampled over a wide area of North America, Canada and Europe. Flavonoid patterns might be useful supplementary data to botanical keys, especially for identification of species in the absence of flowers.

DISTRIBUTION

The distribution of the three most important species of *Elodea* in North America is presented in Figure 5. *Elodea canadensis* is native to temperate North America and is concentrated around the St Lawrence Valley, the Great Lakes, and the Pacific West Coast. *E. nuttallii* has a similar distribution, but is more common further south. *Elodea bifoliata*, in contrast to the other two species, is found in wetlands at higher altitudes.

Of these three species, *E. canadensis* is well known because it aggressively invaded the waterways of Europe in the 19th Century (Sculthorpe 1967, Simpson 1984). After spectacular vigour and dispersal, there was a subsequent decline, but new invasions and explosive growth are still occurring in Norway (Rørslett et al. 1985) and Czechoslovakia (Pokornỳ personal communication). This is especially evident in

Figure 2. *Hydrilla verticillata* (×1, leaf ×1.5) leaves serrulate, in whorls of 3 to 8. (Illustration by Christine Payne, from Sainty and Jacobs 1988).

mesotrophic to eutrophic lakes. It is also now considered a noxious weed in many regions of Asia, Africa, Australia and New Zealand.

E. canadensis is of little economic importance in North America, perhaps because it is eclipsed by more aggressive introduced species, especially *H. verticillata* in Florida and California, *Myriophyllum spicatum* L. (Eurasian Milfoil) in the Pacific Northwest, and *Egeria densa* in North Carolina. Although *E. canadensis* grows in irrigation systems of the Pacific North West and northern California, it is regarded as less troublesome than the *Potamogeton* species found there (R.D. Comes, personal communication). It frequently appears in reports of weed control practice for North America but generally only as a minor component of a submerged flora. Information on the status of the aquatic plants in North America has been documented in proceedings of the US Army Corps of Engineers annual meetings (e.g. US Army Corps of Engineers 1987). In a paper on the effect of submerged aquatic plants on their environment, Godshalk et al. (1987) commented that the littoral vegetation typical of most temperate, hard water, eutrophic lakes is dominated by *Potamogeton nodosus* Poir. and *Ceratophyllum demersum* L, with other species such as *Potamogeton foliosus* Rafin., *Potamogeton pectinatus* L., *Heteranthera dubia* MacMillan, *Najas flexilis* Rostk. and Schmidt and *E. canadensis* also being present.

In New Zealand, *E. canadensis* is widespread and abundant. According to Mason (1975) it was first introduced near Christchurch over a century ago. It may still colonize new waters, as evidenced by its explosive growth in Lakes Rotorua and Rotoiti. The cost, extent, and control of *E. canadensis* and other weed problems was reviewed by Hughes (1976). In Lake Taupo dense stands of aquatic plants interfere with the use of boat ramps. The introduction of *E. canadensis* and *L. major* has exacerbated these problems. *L. major* is now the main weed species in the depth zone 2 to 6.5 m, with *Elodea* growing below this to 10 m (Howard-Williams and Vincent 1983).

During the last 20-30 years, *E. canadensis* has spread rapidly in the irrigation systems of south-eastern Australia. This threatened the efficiency of irrigated agriculture by impeding the flow of water in supply and drainage channels (Aston 1973; Bowmer et al. 1979). Since then *E. canadensis* has declined in some parts of Victoria (Jackel, personal communication). In New South Wales the weed has maintained its density in the Murray Region but has not become widespread or dense in the Murrumbidgee Region.

In Europe, *E. nuttallii* was first identified in 1955. Apparently it is actively spreading in many parts of Europe and seems to be replacing *E. canadensis* in many localities (Simpson 1984). It is also becoming established in many lakes, ponds and streams in Japan (Cook and Urmi-König 1985).

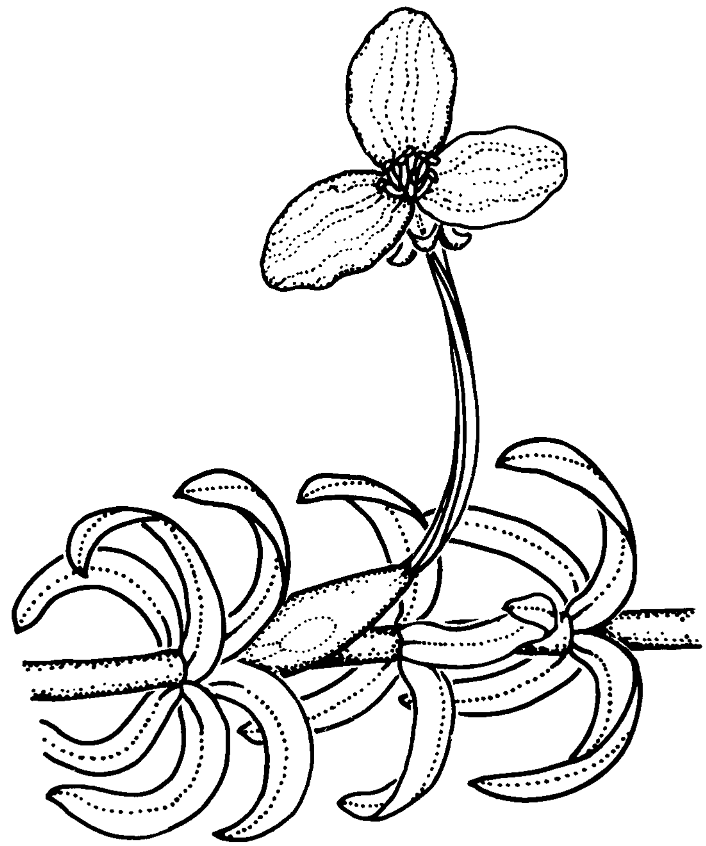

Figure 3. Egeria densa (×0.5) leaves densely clustered towards end of branches, in whorls of mostly 4-5; flowers obvious. (Illustration by Christine Payne, from Sainty and Jacobs 1988).

PHYSIOLOGY

Studies of the physiology of *Elodea* have largely been restricted to *E. canadensis,* because of its well-documented aggressive invasion of alien habitats. This species is a relatively light-demanding plant. It has a high compensation point (Brown et al. 1974) and is not photosaturated with light at three times the levels tolerated by *L. major* and *Egeria densa.* However, light requirements of all the submerged species are complicated by their ability to adapt. Also, at least for *E. canadensis,* physiological response is complicated by the interaction of carbon dioxide and bicarbonate concentration with irradiance (Maberly 1983).

E. canadensis, along with species of *Egeria, Hydrilla, Lagarosiphon,* and some other aquatic plants, is able to transport and fix carbon by using 4-carbon acids to supplement the 3-carbon acid pathway. In the past, these plants were not generally considered to be C_4 plants (Kelly and Latzko 1982). It seems that the enzymes are separated intracellularly rather than intercellularly as in the typical Kranz anatomy. It also seems that the C_4 system operates most of the time but only effectively fixes carbon when carbon availability is low (Bowes and Salvucci 1989). The aquatic variant should be treated as an entity in its own right. *E. canadensis* is also able to use bicarbonate as a carbon source in alkaline conditions either directly (Maberly and Spence 1983, Maberly 1983) or by converting bicarbonate into carbon dioxide by acidification of the cell walls (Prins et al. 1982).

Apart from the availability of nutrients and suitable carbon sources, conditions reported to favour colonization include a silty rather than a sandy substrate (Taylor 1971) and a supply of iron in the reduced form (Olsen 1954). Sculthorpe (1967) speculates that the exhaustion of a critical micronutrient such as iron could explain the decline of

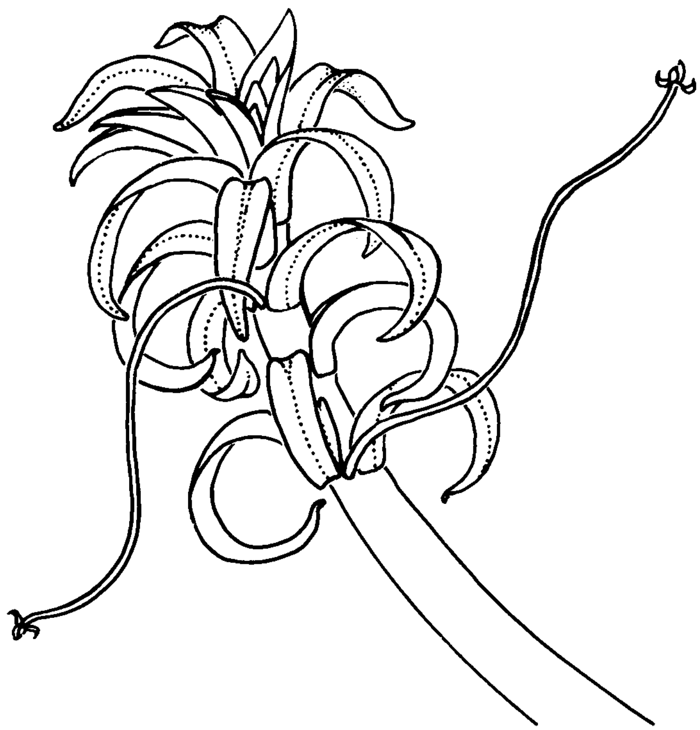

Figure 4. *Lagarosiphon major* (×1.5) leaves alternate spirally around stem, strongly recurved. (Illustration by Christine Payne, from Sainty and Jacobs 1988).

vigour and abundance observed in Europe in the late nineteenth century.

E. canadensis is able to grow slowly under ice cover and can survive inside ice (Sainty and Jacobs 1981).

SURVIVAL

E. canadensis produces vegetative propagules at the onset of winter or in unfavourable conditions. These condensed shoots are able to root readily at the nodes. Pieces continue to grow while floating in the water. Plants overwinter in the mud in the form of swollen shoot apices, and populations are rapidly re-established when these grow out as leafy stems in the spring (Bowmer et al. 1984). Not much is known about the biology of *E. nuttallii.* In Japan and Switzerland prostrate shoots with green leaves overwinter, forming dense mats on the bottom. Male and female flowers of both *E. canadensis* and *E. nuttallii* have been recorded in North America but ripe seeds of *E. canadensis* are rare. Cook (1982) has a possible explanation for this, noting that fruiting stems become heavy and sink to the bottom. *E. bifoliata* is highly fertile (Cook and Urmi-König 1985).

DISPERSAL

Ripe seeds have rarely been recorded and, even allowing for the observation made by Cook (1982) that fruiting bodies become heavy and sink to the bottom, it seems that spread by fruit is not particularly important in areas where *Elodea* has become a weed. In those countries where flowers of only one sex have been recorded the spread appears to be hampered little, if at all. In Australia and Ireland only male flowers have been recorded whereas in New Zealand and Europe only female flowers have been recorded. In all cases the only restriction to the spread of *Elodea* appears to have been environmental. In Australia, for example, *Elodea* is found only in cold water. Large channels may contain *Elodea* but it rarely becomes established in the shallower feeder channels at the edge of its distributional range.

Introduction into a country has almost certainly been via the trade in live aquarium plants, legal or otherwise. Once plants have become established in the wild, probably most frequently from discarded aquaria contents, dispersal has mostly been by stem fragments floating downstream. Dispersal between catchments is likewise by stem fragments. Stem sections become caught in boat propellers or trailers, in vehicles crossing fords, in maintenance equipment, by wildlife, or actively man-assisted. In the absence of fruits, some dispersal is possible via the modified vegetative buds (or ‘double nodes’, Haramoto and Ikusima 1988). These unique structures are able to survive periods of desiccation and/or low temperatures. As a result, vegetative buds are possibly more easily distributed between catchments (distance dispersal) than stem fragments by wildlife.

REVIEW OF MANAGEMENT

Elodea canadensis is a stubborn weed in some parts of the world. It is especially obstructive to channel flow in the irrigation districts of south eastern Australia. The only economical, safe and effective methods of controlling *Elodea canadensis* are by draining and drying the channel or water body, by the application of herbicides (notably acrolein and fluridone) and where permitted, by the introduction of herbivorous fish.

Biological control. The problems and potential benefits of management of submerged plants with grass carp (*Ctenopharyngodon idella*) were reviewed (Pauley et al. 1987, Bonar et al. 1987). Many authors agree that *E. canadensis* (along with *Vallisneria* sp.; *Potamogeton crispus* L., *P. ochreatus* Raoul, *P. pectinatus* and *P. zosteriformis* Fernald) is palatable to the carp, and preferred over some other weed species. Bowers et al. (1987) report that some other important weed species such as *Myriophyllum spicatum* and *Ceratophyllum demersum* are ‘variably preferred’, while *Potamogeton natans* L. and *Egeria densa* are at the bottom of the list. As noted by Fowler and Robson (1978) there is concern that in mixed plant assemblages (such as often found in more temperate lakes), the effect of the carp may be to increase the biomass of unpalatable species at the expense of the more palatable ones.

Another potential biocontrol agent has been detected in a field study in Australia (Burrows 1993) where the effectiveness of the hydrilla leaf-mining fly, *(Hydrellia balciunasi* Bock) and the hydrilla stem boring weevil (*Bagous hydrilla* O’Brien) were evaluated. Both these insects have been released in the USA for the control of *Hydrilla.*

Harvesting. Mechanical methods (cutting, draglines etc.) are not usually recommended as they break up the plant allowing it to spread to new areas. But harvesting can be quite useful in areas where the weed is already established or

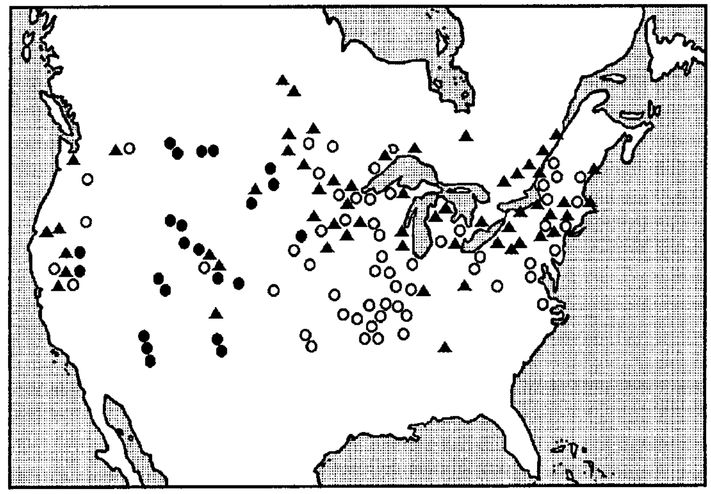

Figure 5. Distribution of *Elodea bifoliata* (•), *Elodea nuttallii* (°) and Elodea canadensis (▲) in North America (modified from Cook and Urmi-König 1985).

when the weed will disperse into areas unfavourable to its survival.

Draining. Hejny and Husák (1978) comment that control in Czechoslovakia is simply effected by a combination of summer and winter drainage. Winter frost also helps in these climates. In Australia, control is aided by draining and exposure of sediments to high summer temperatures or winter frosts, but draining for sufficient time is not always feasible, especially in larger canals.

Herbicides. E. canadensis is difficult to control with herbicides. Possible explanations include the protective effect of heavy coatings of bacteria and aufwuchs (detritus, algae, bacteria and inorganic particulates) on the leaves of the plants. The role of bacteria in protecting *E. canadensis* against diquat was demonstrated by Whitfort (1982) using plants grown axenically or colonized by *Pseudomonas* or *Bacillus* spp. Similarly, Bowmer (1982b) demonstrated that aufwuchs washed from the leaves of *E. canadensis* would contribute to the loss of toxic effect.

Another problem is the difficulty of penetrating very dense weed beds with herbicides as described by Bowmer et al. (1985) in their attempts to control *E. canadensis* with terbutryne. Several herbicides seem to require long contact times for effective control, for example, fluridone (1-methyl-3-phenyl-5-[3-(trifluromethyl) phenyl]-4(1H)-pyridinone), endothal (7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid) and terbutryne (2-(tert-butylamine)-4-(ethylamino)-6-(methyl-thio)-s-triazine). This makes management difficult in flowing water. Herbicides preferred for their margins of safety for water users and aquatic life (for example the potassium salt of endothal) seem to be ineffective.

Diquat (6,7-dihydrodipyrido[1,2-∝:2,1-c]pyrazinediium) and copper sulphate or chelates of copper can be used in static water. The addition of copper is reputed to improve control compared with diquat alone, and is also advantageous because algae are inhibited. Paraquat ($1,1^{1}$-dimethyl-$4,4^{1}$-bipyridinium(I)) and diquat mixtures are used in Czechoslovakia, but these promote the subsequent growth of filamentous algae. Diquat is ineffective in turbid waters because it is inactivated by adsorption to soil particles (Bowmer 1982a).

Elodea canadensis, Egeria densa and *Hydrilla verticillata* are known to be sensitive to fluridone (McCorkelle et al. 1992a). But reliable control requires static water and the total treatment of a pond or lake. In slow-moving water the effectiveness of fluridone is reduced. Label recommendations are that water bodies should be maintained static for at least seven days after treatment to enable adequate uptake of herbicide by the plants. Use of fluridone in the irrigation channel systems of Australia may be limited because of potential damage to susceptible crops, especially rice.

Terbutryne is used for control of various submerged weeds including *E. canadensis* in Europe (Murphy 1982), and in Ontario (MacKenzie et al. 1983). For treatment of lakes and storages this compound has many advantages, which include longer-term control of macrophytes, suppression of algae, and greater safety for non-target aquatic organisms including fish (Aston and Reynaert 1974). It has been considered for use in temperate lakes for control of *Myriophyllum spicatum*, but not *Elodea canadensis.* Treatment of flowing water would be impractical because of the extensive contact time required for the herbicide to be effective (Bowmer et al. 1985).

Acrolein (acrylaldehyde) gives temporary control in flowing water. It is injected into the water and allowed to flow over the weed beds. Application is restricted to approved operators. It is used in several States of North America, mainly in the Pacific Northwest, for treatment of a mixed spectrum of submerged weeds in irrigation distribution systems. In Australia, the sensitivity of different species in a trial was *Vallisneria* spp. >*Elodea canadensis* >*Potamogeton tricarinatus.* Therefore repeated treatment may disadvantage the desirable native *Vallisneria,* and favour the troublesome and obstructive native *Potamogeton* (Bowmer and Smith 1984). The optimisation of acrolein use, including the economy of multiple additions to compensate for rapid loss from flowing water, is described by Bowmer and Sainty (1977).

Bensulfuron methyl (Methyl 2[[[[[(4,6 dimethoxy pyrimidin-2-yl)amine] carbonyl]amino]sulfonyl]methyl]benzoate) showed great potential for control of *Hydrilla verticillata* by inhibiting tuber formation (Anderson and Dechoretz 1988). In Australia, *Elodea canadensis* is tolerant to bensulfuron methyl (McCorkelle et al. 1992b). Bensulfuron methyl is the active ingredient of both Londax®, a herbicide used in rice production, and Mariner®, a herbicide that was under evaluation for use in aquatic environments. In late 1992, work on the registration of Mariner® was stopped because it had accumulated temporarily in freshwater clams, a monitoring organism (Anon 1992).

Other herbicides reported to be used in management include:

(i) for injection into flowing water: aromatic solvent and emulsifier; anhydrous ammonia; copper sulphate (dumped or continuously fed into the water); and the liquid formulation of endothal alkylamine.

(ii) for treatment of ponded water: ametryn (2-ethylamino-4-isopropylamino-6-methyl thio-1,3,5-triazine); anhydrous ammonia; copper sulphate; endothal alkylamine (liquid or granular formulations); hexazinone (3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5,triazine-2,4(1H,3H)-dione); simazine (2-chloro-4,6-bis(ethylamino)-s-triazine); and terbutryne granules.

(iii) for use as soil residual herbicides, after channel drainage: chlorfenac (dichlobenil(2,6-dichlorobenzonitrile); and simazine.

Many of these herbicides are no longer permitted for use in most aquatic situations (e.g. chlorfenac, hexazinone). Some are of doubtful efficacy (e.g. dichlobenil used as a soil residual herbicide) and all are restricted by situation and water use. The subject was reviewed by Bowmer et al. (1979) and Bowmer (1987).

ACKNOWLEDGMENTS

We are grateful to Mike Boulton and Laurie Jackel for information on the distribution and importance of *Elodea canadensis.*

LITERATURE CITED

Anderson, L.W.J. and N. Dechoretz. 1988. Bensulfuron methyl: A new herbicide. *In*: Proceedings, 22nd Annual Meeting, Aquatic Plant Control Research Program, 16-19 November 1987, Portland Oregon, Environmental Laboratory, US Army Engineers Waterways Experiment Station, Vicksburg, MS pp. 224-235.

Anonymous. 1992. Du Pont halts work on Mariner, Aquaphyte, University of Florida, Gainesville, p. 2.

Aston, H.I. 1973. Aquatic Plants of Australia. Melbourne University Press, pp. 216-217.

Aston, J.L. and J. Reynaert, J. 1974. The current and potential use of the triazine herbicides in water. Proceedings of the EWRS 4th Symposium on Aquatic Weeds, pp. 244-252.

Bonar, S.A., G.L. Thomas, and G.B. Pauley. 1987. Estimation of triploid White Amur stocking densities for aquatic plant control for Devils Lake, Oregon, Proceedings 21st Annual Meeting Aquatic Plant control Research Program, Miscellaneous Paper A-87-2, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, pp. 122-132.

Bowes, G. and M.E. Salvucci. 1989. Plasticity in the photosynthetic carbon metabolism of submersed aquatic macrophytes. Aquat. Bot. 34:233-266.

Bowers, K.L., G.B. Pauley, and G.L. Thomas. 1987. Feeding preference on Pacific Northwest aquatic plant species by diploid and triploid Grass Carp (*Ctenopharyngodon idella*). Proceedings 21st annual Meeting Aquatic Plant Control Research Program, Miscellaneous Paper A-87-2, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, pp. 133-140.

Bowmer, K.H. 1982a. Adsorption characteristics of seston in irrigation water: implication for the use of aquatic herbicides. Aust J Mar Freshwater Res, 33:443-458.

Bowmer, K.H. 1982b. Aggregates of particulate matter and aufwuchs on *Elodea canadensis* in irrigation waters, and inactivation of diquat. Aust J Mar Freshwater Res, 33:589-593.

Bowmer, K.H. 1987. Herbicides in surface water. *In:* Herbicides, D.H. Hutson and T.R. Roberts, eds., John Wiley & Sons Ltd, Chichester, pp. 271-355.

Bowmer, K.H., D.S. Mitchell, and D.L. Short. 1984. Biology of *Elodea canadensis* Mich. and its management in Australian irrigation systems. Aquat. Bot. 18:231-238.

Bowmer, K.H. and G.R. Sainty. 1977. Management of aquatic plants with acrolein. J. Aquat. Plant Manage. 15:40-46.

Bowmer, K.H., G.R. Sainty, G. Smith and K. Shaw 1979. Management of Elodea in Australian irrigation systems. J. Aquat. Plant Manage. 17:4-12.

Bowmer, K.H., K. Shaw and J.A. Adeney. 1985. Management of submerged aquatic macrophytes with terbutryne: availance, phytotoxicity and persistence. Weed Res. 25:449-459.

Bowmer, K.H. and G.H. Smith. 1984. Herbicides for injection into flowing water: acrolein and endothal-amine. Weed Res. 24:201-211.

Brown, J.M.A., F.I. Dromgoole, M.W. Towsey, and J. Browse. 1974. Photosynthesis and photorespiration in aquatic macrophytes. *In*: Mechanisms of Regulation of Plant Growth, R.L. Bieliski, A.R. Ferguson, and M.M. Cresswell, eds., The Royal Society of New Zealand, Wellington, pp. 243-249.

Burrows, D. 1993. ASL Newsletter 31(1),58.

Cook, C.D.K. 1982. Pollination mechanisms in the Hydrocharitaceae. *In*: Studies on Aquatic Vascular Plants, J.J Symoen, S.S. Hooper and P. Compère, eds., Royal Botanical Society of Belgium, Brussels, pp. 1-15.

Cook, C.D.K. and K. Urmi-König. 1985. A revision of the genus *Elodea* (Hydrocharitaceae). Aquat. Bot. 21:111-156.

Correll, D.S. and H.B Correll. 1975. Aquatic and Wetland Plants of Southwestern United States, University Press, Stanford, California, pp. 163-167.

Fowler, M.C. and T.O. Robson. 1978. The effects of the food preferences and stocking rates of grass carp (*C. idella*) on mixed plant communities. Aquat. Bot. 5:261-276.

Godshalk, G.L., J.W. Barko, and W.F. James. 1987. Effects of submersed aquatic plants on their environment. Proceedings 21st Annual Meeting Aquatic Plant Control Research Program, Miscellaneous Paper A-87-2, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, pp. 215-224.

Haramoto, T. and Ikusima, I. 1988. Life cycle of *Egeria densa* Planch., an aquatic plant naturalized in Japan. Aquat. Bot. 30:389-403.

Hejny, S. and S. Husák. 1978. *In*: Pond Littoral Ecosystems Structure and Functioning, D. Dykyjová and J. Kvet, eds. Springer-Verlag, Berlin, pp. 36-37.

Howard-Williams, C. and W.F. Vincent. 1983. Plants of the littoral zone. *In* Lake Taupo: ecology of a New Zealand lake, D.J. Forsyth and C. Howard-Williams, eds., Science Information Publishing Centre, Department of Scientific and Industrial Research, Wellington, New Zealand. pp.73-84.

Hughes, H.R. 1976. Research into aquatic weeds in New Zealand waterways: a review. DSIR Information Series No. 116, N.Z. Department of Scientific and Industrial Research, 34pp.

Keeley, J.E. 1990. Photsynthetic pathways in freshwater aquatic plants. Trends in Ecology and Evolution 5:330-333.

Kelly, G.J. and E. Latzko. 1982. IV. Photosynthesis. Carbon metabolism: the profound effects of illumination on the metabolism of photosynthetic cells. Prog Bot 44:103-131.

Maberly, S.C. 1983. The interdependence of photon irradiance and free carbon dioxide or bicarbonate concentration on the photosynthetic compensation points of freshwater plants. New Phytol. 93:1-12.

Maberly, S.C. and D.H.N. Spence. 1983. Photosynthetic inorganic carbon use by freshwater plants. J. Ecol. 77:705-724.

Mason, R. 1975. The Macrophytes. *In*: New Zealand Lakes V.H. Jolly and J.M.A. Brown, eds., Auckland University Press; Oxford University Press, pp. 239-240.

Mackenzie, D., R. Frank, and G.J. Sirons. 1983. Aquatic plant control and disappearance of terbutryne from treated waters in Ontario, Canada 1974-1977. J. Aquat. Plant Manage. 21:11-16.

McCorkelle, G., G.R. Sainty and K.H. Bowmer. 1992a. Evaluation of Sonar (Fluridone) for aquatic plant management in Australia. Final report for Dow Elanco Australia Ltd, Consultancy Report No 92/2. CSIRO Division of Water Resources, Griffith NSW. 58pp.

McCorkelle, G., G.R. Sainty and K.H. Bowmer. 1992b. Use of Bensulfuron in irrigation supply systems in Australia. Report for Du Pont (Australia) Ltd, Consultancy report No 93/43. CSIRO Division of Water Resources, Griffith NSW. 20pp.

Mues, R. 1983. Species specific flavone glucoronides in *Elodea* species. Biochem Syst Ecol 11:261-265.

Murphy, K.J. 1982. The use of methylthiotriazines in fresh-water systems: a review. Proceedings of the EWRS 6th Symposium on Aquatic Weeds, pp. 263-277.

Olsen, C. 1954. Mvilke betingelser ma voere opfyldte for at *Elodea canadensis* kan opna den optimale udvikling, der er arsag til dens massevise optraeden in naturen? [What are the conditions of optimum development enabling *Elodea canadensis* to grow profusely in nature?] Botanisk Tidsskrift 51: 271-273.

Pauley, G.B., G.L. Thomas, S.L. Thiesfeld. S.A. Bonar, and K.L. Bowers. 1987. An overview of the use of triploid Grass Carp (*Ctenopharyngodon idella*) as a biological control of aquatic macrophytes in Devils Lake, Oregon, Proceedings 21st Annual Meeting Aquatic Plant Control Research

Program, Miscellaneous Paper A-87-2, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, pp. 115-121.

Prins, H.B.A., J.F.H. Snel, and P.E. Zanstra. 1982. The mechanism of photosynthetic bicarbonate utilization. *In*: Studies on Aquatic Vascular Plants, J.J. Symoens and S.S. Hoor, eds., Royal Botanical Society of Belgium, pp. 120-126.

Rørslett, B., D. Berge, and S.W. Johansen. 1985. Mass invasion of *Elodea canadensis* in a mesotrophic, South Norwegian lake - impact on water quality. Verh. Internat. Verein. Limnol. 22:2920-2926.

Sainty, G.R. and S.W.L. Jacobs. 1981. Waterplants of New South Wales. Water Resources Commission of New South Wales. 550pp.

Sainty, G.R. and S.W.L. Jacobs. 1988. Waterplants in Australia, Sainty & Associates. Sydney, pp. 65-71.

Sculthorpe, C.D. 1967. The Biology of Aquatic Vascular Plants, Edward Arnold, London, 610 pp.

Simpson, D.A. 1984. A short history of the introduction and spread of *Elodea* Michx in the British Isles. Watsonia 15:1-9.

Taylor, M.E.U. 1971. A study of elodea growth in some low-nutrient lakes. *In*: Symposium on Natural Water Quality and Waste Treatment Technology, Massey University, New Zealand, pp. 27-38.

US Army Corps of Engineers. 1987. Proceedings 21st Annual Meeting Aquatic Plant Control Research Program, Miscellaneous Paper A-87-2, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, pp. 5-30.

Whitfort, L.A. 1982. Investigations into the composition of epiphytic communities and their influence on the uptake of diquat by *Elodea canadensis* Rich. MSc. Thesis, University of New South Wales; CSIRO Division of Irrigation Research, Griffith, New South Wales, 132 pp.