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Invasion of Egeria into the Hawkesbury-Nepean River, Australia

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INTRODUCTION

Macrophytes are considered important components to the ecology of estuaries and freshwater ecosystems (Westlake 1975). Their role as structural habitats and food sources for invertebrates, fish and birds, effectiveness in reducing stream bank erosion, and removing excessive nutrients (Carpenter and Lodge 1986, Barko et al. 1991, Hart et al. 1993) suggests their importance to environmental managers.

The Hawkesbury-Nepean River in New South Wales (NSW), Australia, is the largest river system in the Sydney metropolitan area, and it drains most of the developing areas to the west. This catchment is under increasing pressure from urban expansion and the river frequently experiences extended periods of low flows due to a combination of extensive river regulation and the Australian temperate climate. Added to this, the river and several of its tributaries receive treated sewage and stormwater from various sources.

Habitats and biota within the Hawkesbury-Nepean River catchment have been altered since European settlement and many introduced species have spread throughout the terrestrial and aquatic environment (Recher et al. 1993). Submersed macrophyte assemblages within the river have undergone significant changes in their distribution and abundance due to eutrophication, habitat alteration and changes to river flows (Recher et al. 1993). Anecdotal evidence and some early unpublished studies[3,4] suggest that ege-

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[3]Harris, J. 1983. Report on sand and gravel extraction from the Hawkesbury River. Unisearch Limited, University of NSW, Report. 4 pp.

[4]Hunt, D., and B. Simmons. 1986. Distribution of macrophytes in the freshwater section of the Hawkesbury River. State Pollution Control Commission NSW, 35 pp.

ria (*Egeria densa* Planchon), introduced from South America as an aquarium plant, was present in the Hawkesbury-Nepean River prior to 1980. Sainty (1973) reported a persistent and troublesome infestation over a number of years at Wallacia in the upper Nepean River.

Egeria occurs throughout coastal NSW (Sainty and Jacobs 1981), but to date has not caused the same problems as in the United States, Japan and New Zealand. In New Zealand, it has become widespread and its competitive ability has allowed it to successfully dominate and in some cases displace assemblages of native aquatic plants (Clayton 1996).

Here, as part of a larger study on the ecology of macrophyte and invertebrate assemblages associated with anthropogenic disturbance in the Hawkesbury-Nepean River, we document the rapid spread of egeria since 1994. Significant increases in egeria biomass were also found, and we present preliminary evidence which suggests that the native ribbon weed, vallisneria (*Vallisneria americana* Michx.), is being displaced.

MATERIALS AND METHODS

In 1994, the submersed macrophytes within the Hawkesbury-Nepean River were mapped between Warragamba Dam and Wiseman's Ferry to ascertain their large-scale distribution (Figure 1). Vegetation was mapped using a 4.5m Marlin Broadbill equipped with a Garmin-75 Global Positioning System (GPS) navigator, a Furuno paper sounder and a 3d Hummingbird sounder. These remote techniques were used in conjunction with "ground-truthing" using SCUBA. Macrophyte beds were directly recorded onto copies of 1:8000 scale air photographs using relative distances obtained with the GPS and depth sounders. For each bed, its size, species composition and depth were recorded.

During this mapping exercise, we found that egeria had spread into areas where it had not been previously reported (Figure 1). The distribution of egeria was further determined during 1996, and its spread estimated (Figure 1).

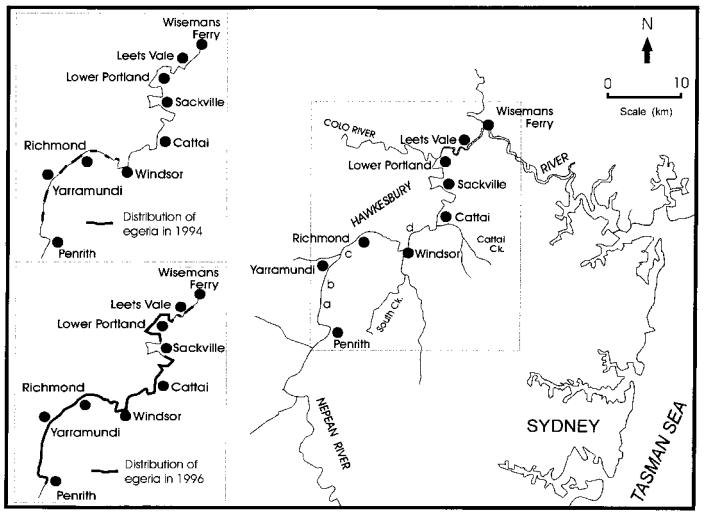

Figure 1. Extent of egeria in the Hawkesbury-Nepean River in 1994 and 1996 and the location of the sites at (a) Smith Street, (b) Devlin Street, (c) North Richmond and (d) York Reach.

Also, at five randomly selected times (between September 1995 and October 1996) the biomass of both egeria and vallisneria were recorded from four fixed sites within the Hawkesbury-Nepean River. At each site, three macrophyte beds (> 5m^2) were randomly selected and SCUBA divers harvested aboveground biomass samples from five randomly placed quadrats (0.04 m^2) in each bed. The biomass samples were sorted into species and oven dried to constant weight at 105 C for 48 hours prior to weighing to the nearest 0.01 g (Madsen 1993).

A mixed-model nested analysis of variance was used to test the null hypothesis that there were no spatial or temporal differences in the biomass of egeria or vallisneria. The site factor was considered fixed whilst time was considered random. The random "macrophyte" bed factor was nested within the interaction of the two main effects. The bed (time x site) term is valid because beds were haphazardly selected on each sampling occasion. The assumptions of normality and homogeneity of variances were checked prior to analysis of variance (Underwood 1981).

RESULTS AND DISCUSSION

During our 1994 mapping study, we estimated that egeria occupied approximately 1.1 km^2 of river. In 1996, it was estimated that egeria occupied approximately 2.1 km^2 of riverbed within the 11.7 km^2 stretch of the Hawkesbury-Nepean River between Warragamba Dam and Wisemans Ferry (Figure 1). The fresh weight of egeria in the river during 1994 was estimated to be 9,500,000 kg, whereas by 1996 the estimated fresh weight was around 19,000,000 kg.

In both 1994 and 1996, no exotic macrophytes were found between Warragamba Dam and Penrith Weir. Mixed beds of potamogeton (*Potamogeton tricarinatus* A. Benn. & F. Muell.), vallisneria, hydrilla (*Hydrilla verticillata* (L.f.) Royle.), and najas (*Najas browniana* Rendle.) were common in this stretch of the river.

In 1994, vallisneria, egeria, and in some places waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) were observed to dominate aquatic plant assemblages below Penrith Weir. This section of river is variable in its geomorphology; between Penrith Weir and Yarramundi, it is largely shallow sandy floodplains and riffle zones with small ponded areas. By April 1996, egeria primarily covered this section of the river except where river flow was high in riffle zones.

In 1994, vallisneria was observed to be the dominant macrophyte species from Yarramundi to Windsor; however, by April 1996, egeria had infiltrated vallisneria beds and in some cases displaced them. In 1994 and 1996, vallisneria was the dominant species from Windsor to Wisemans Ferry but by April 1996, egeria had established itself as far down the river as Wisemans Ferry.

Analysis of the biomass of egeria and vallisneria at four fixed sites (Site 1—Smith Street; Site 2—Devlin Street; Site 3—North Richmond; Site 4—York Reach) revealed significant Time x Site and Bed (Time × Site) interactions ($P <$ 0.01) for both species (Figure 2). Comparisons of means (SNK tests) revealed significant differences between sites and times. At the Smith Street site, the abundance of egeria increased significantly between September 1995 and October 1996 (Figure 2a) and was concomitant with a significant

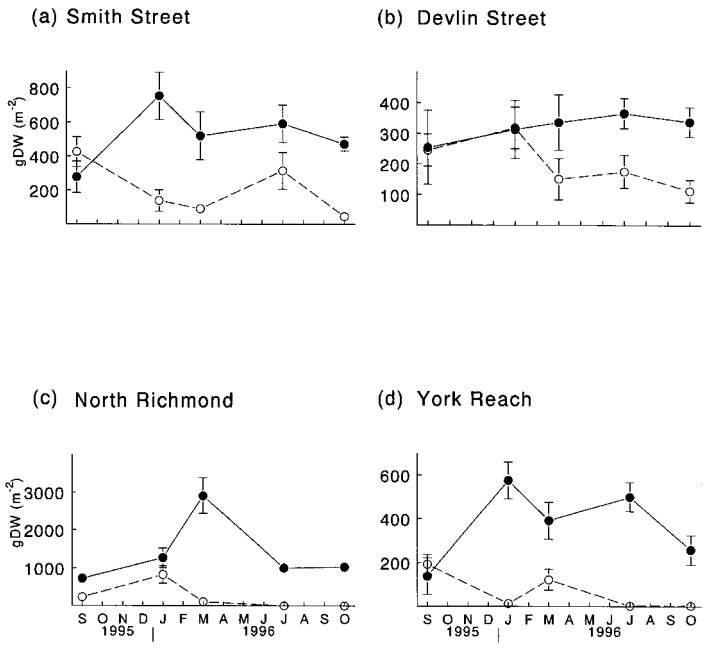

Figure 2. Mean (± 1 standard error of the mean) biomass estimates (dry weight in *g* m^{-2}; *n* = 15) for egeria (•) and vallisneria (○) from 4 fixed sites and 5 times.

decrease in the abundance of vallisneria (Figure 2a). At the Devlin Street site, egeria did not increase significantly through time, however a significant decrease in the abundance of vallisneria was recorded (Figure 2b).

At the North Richmond site, the abundance of egeria increased three-fold between January 1996 and March 1996 but by July 1996 had declined to abundance's similar to September 1995 (Figure 2c). The abundance of vallisneria, however, declined significantly and by July of 1996 had all but disappeared from this location. Similarly, at the York Reach site (Figure 2d) the abundance of egeria increased significantly between September 1995 and October 1996 whilst the abundance of vallisneria declined (Figure 2d).

The process by which egeria displaced vallisneria in the Hawkesbury-Nepean River is uncertain, however competition for light is highly conceivable. Egeria has large densely clustered leaves towards the end of its branches and like hydrilla, can form dense surface covers (Haller and Sutton 1975, Sainty and Jacobs 1994). Haller and Sutton (1975) demonstrated that hydrilla could out-compete vallisneria because its dense surface cover effectively limited light penetration to the first 0.3 m in the water column.

The limited amount of historic data suggests that egeria was not present in the Hawkesbury-Nepean River in any great abundance prior to at least 1986. There was some account of its occurrence in the Wallacia area (Sainty 1973) but it appeared to be a small component of the submersed plant assemblages. The rapid increase in the distribution and abundance of egeria over the past three years is of major concern for the Hawkesbury-Nepean River. Our data indicate the potential for native species such as vallisneria to be displaced relatively quickly by this exotic species. In New Zealand, egeria established itself in the late 1960s after which its spread was extremely rapid (Chapman et al. 1974, Clayton 1996).

The ability of egeria to thrive in slow flowing waterbodies containing high nutrients is well-documented (Sainty and Jacobs 1981). The Hawkesbury-Nepean River is considered to be eutrophic because the median total phosphorous (TP: 95 μg L^{-1}) and nitrogen (TN: 1.3 mg L^{-1}) concentrations exceed the Australian water quality guidelines (TP: 50 μg L^{-1}; TN: 1.0 mg L^{-1}) for fresh waters (ANZECC 1992). Over the last few years, low flows have occurred which may also be assisting egeria in establishing itself as the community dominant (Cummins et al. 1997).

Egeria and similar species slow water flow substantially and increase siltation rates (Graham 1976, Carpenter and Lodge 1986). Macrophytes have the ability to remove excess nutrients from waterbodies (Carpenter and Lodge 1986, Rattray et al. 1991). Therefore, one could conclude that a proliferation of nutrient removing plants would be beneficial to a river system that was highly eutrophic. However, Graham (1976) reports that concentrations of dissolved ammonia, nitrate and phosphorous were not depleted in beds of thick egeria compared with open water.

Significant flood events over the past year have not reduced the abundance of egeria but appear to have caused its spread downstream. For example, in January 1995, fragments and whole plants of egeria became detached from beds between Penrith and Richmond and were transported down the river during a high-flow flood event. Since that time, egeria has increased its range downstream into the Hawkesbury River, as fragments of the plant are capable of vegetative reproduction (Sainty and Jacobs 1981).

The rapid infestation of egeria into the Hawkesbury-Nepean has the potential to adversely affect the river by restricting navigation and boating, clogging irrigation and water supply systems, and slowing river flow. In addition, dense beds of egeria alter the distribution and abundance of native macrophyte and invertebrate assemblages, block the migration of fish, affect water chemistry, depreciate monetary and aesthetic value of waterfront, and severely limit recreational usage.

In the course of two years, growing restrictions to navigation and the loss of native macrophyte habitats have become evident. Egeria has been present in Australia for many years and has not yet caused any troublesome or prolonged weed infestations, thus there is a risk that water managers have become complacent about its potential threat. However, it has been a major problem in other parts of the world with rivers comparable with the Hawkesbury-Nepean and the presence of this plant should always be treated seriously. Future management of the Hawkesbury-Nepean River and the issues associated with low river flows need to address the proliferation and expansion of egeria.

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