Distribution and spread of the Alismataceae in the rice-growing region of New South Wales

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Abstract

McIntyre[1], S. and Newnham[2], M. R. (CSIRO Centre for Irrigation Research, Griffith, Australia 2680) 1988. Distribution and spread of the Alismataceae in the rice-growing region of New South Wales. Cunninghamia 2(1): 25–38. — The distributions of five species of the Alismataceae are described for the rice-growing region of New South Wales. Two native species occur in the area: *Alisma plantago-aquatica* L. is uncommon, but *Damasonium minus* (R. Br.) Buch. is widespread in wetlands and extremely abundant in rice fields, where it is regarded as a major weed.

Irrigation development has enhanced the introduction and spread of aquatic plants and three members of the Alismataceae have entered the region in the last 20 to 30 years. Within the irrigation areas, the plants have dispersed along irrigation channels and all three have been recorded in rice fields. *Sagittaria montevidensis* Cham. *et* Schlecht. is already widespread in the study area but remains a relatively minor weed of rice. *Alisma lanceolatum* With., although still restricted in distribution, has developed extremely high population levels in rice. *Sagittaria graminea* Michx. is also restricted, but shows more potential as a weed of irrigation channels than of rice fields.

Introduction

The development of irrigation on the Riverine Plain in New South Wales has resulted in some major changes to the region. In the irrigated areas human settlement has greatly intensified and there has been a marked increase in the extent of aquatic habitats. Drainage and supply channels, roadside ditches, irrigated pasture and rice crops are examples of aquatic habitats that have been created in addition to, and have sometimes replaced, the natural wetlands.

Many species of the original wetlands and swamps have successfully colonised these new habitats. In addition, introduced aquatic species have entered the region, assisted by human activity.

The Alismataceae is a family of aquatic plants, represented in the region by five species. Two of these, *Alisma plantago-aquatica* L. and *Damasonium minus* (R. Br.) Buch. are native, and three species are introductions: *Alisma lanceolatum* With., *Sagittaria montevidensis* Cham. *et* Schlecht. and *Sagittaria graminea* Michx. All five species have been recorded in rice fields in the study area.

This paper documents the history of introduction and current distribution of the Alismataceae in the rice-growing areas of New South Wales. The three introduced species are still spreading and have not yet achieved their potential distribution. The information on these three species is presented in detail; it is hoped that this will permit useful documentation of the colonising process.

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Methods

Search strategies

The search areas included the Murrumbidgee, Coleambally and Tullakool Irrigation Areas (I.A.) and the Benerembah, Tabbita and Murray Valley Irrigation Districts (I.D.), a total of over one million hectares. Some additional aquatic habitats were also visited, notably those found in the riverine forests associated with the Murray and Murrumbidgee Rivers. Two alternative search strategies were used to locate the plants, the choice depending on the known abundance of each species..ch

Plants known to be restricted in occurrence. With such an extensive area under study, it was impractical to examine systematically the entire area in detail. Instead, searches radiated from known occurrences and were continued until it was evident that the whole local population had been delineated. Additional searching on a less intensive scale was then conducted over a large area surrounding the known infestations to pick up any satellite populations. This strategy was effective for delineating known occurrences but may have resulted in some isolated localised populations being missed.

Localised populations of restricted species were mapped in detail. These data, together with information from local people, provided evidence for determining possible modes of introduction and spread of the plants.

Plants known to be widely distributed. For widely occurring species, distributions were recorded as points on a map, each represented by a plant collection. Efforts were made to obtain an even spread of points over the entire area in which the species was known to occur.

Plant collections

Collections were made with the intention of fully representing the distribution of each species. Specimens were lodged at the National Herbarium of New South Wales (NSW). All collections were made from January to April 1985, with the exception of several *Sagittaria graminea* specimens which were collected in May 1984.

Where collections were made, local population numbers were estimated on the following scale:

<10	very low
10–100	low
100–1000	medium
1000–10 000	high
>10 000	extremely high

For most species, these values represented numbers of individual plants. An exception was the vegetatively reproducing *Sagittaria graminea*, for which population estimates represented numbers of visually identifiable ramets that look superficially like individual plants but may be joined underground.

Definition of terms

Irrigation channel. This term is used collectively to include supply and drainage channels.

Supply channel. An artificially constructed watercourse for the transport of water from the sources of supply (Murrumbidgee and Murray Rivers) to the farms in the Irrigation Areas and Districts. They are generally filled with water throughout the summer and vary in size depending on the location. Major supply channels are

over 20 m wide, while on-farm channels are only a few metres wide.
Drainage channel. These may be natural or artificially constructed watercourses which remove excess water from irrigated land. They are generally shallower than supply channels of equivalent width.
Borrow pit. Flood irrigation is the most common watering method in the region and contour banks are constructed within paddocks to control water movement. When rice is grown, these form the boundary of the bays that remain flooded throughout the season. Borrow pits are narrow ditches that run parallel to the contour banks and are excavated when soil is 'borrowed' to form the bank. They assist in the drainage of water from the paddock and are not generally sown with rice. Consequently, they can provide an open flooded area for the establishment of aquatic plants.
Ditch. This refers to any narrow excavation designed for the collection of water, that is not directly associated with the drainage and supply of irrigation water.

Results and Discussion

Alisma species

Background. *Alisma lanceolatum* is native to Europe, North Africa and West Asia and has since been introduced to Canada, Chile (Häfliger *et al.* 1982) and Australia where it established at Creswick, Victoria some fifty years ago (Aston 1977). The only other collections of *A. lanceolatum* in Australia are from the Mt Lofty Ranges (S.A.), Woori Yallock (Vic.) and Echuca (Vic.). In 1983 it was collected from a rice crop in the Coleambally Irrigation Area, the first record of this species in New South Wales.

Alisma lanceolatum is a principal weed of rice in Southern Europe (Catizone 1981). Barrett and Seaman (1980) also record it for Californian rice fields, where it is rare and not considered to be of importance. Predicting how troublesome *A. lanceolatum* will become in Australian rice fields is guesswork, but the nature and extent of the original infestation in rice suggests that it may be a problem.

Established populations of *A. lanceolatum* were found in the central Coleambally Irrigation Area and the Deniboota Irrigation District, and these are described in detail. The plant was also found in large numbers in drainage channels and roadside ditches in dairying land around Echuca township (Figure 1). These three occurrences are almost certainly disjunct, but it is possible that some isolated populations remain unrecorded in the intervening areas. The method of dispersal and source of material introduced to each of the three sites is unknown, however evidence suggests that the Coleambally and Deniboota infestations originated from separate, long-distance dispersal events.

A second *Alisma* species, *A. plantago-aquatica*, is native to the area but is rare (Figure 1). Although a common rice weed in Brazil, Chile (Gonzalez, Garcia & Perdomo 1983) and in eastern Europe (Podkin, Chanukvadze & Frolova 1983), *A. plantago-aquatica* has been found only as a few plants in two rice crops in New South Wales and is not considered to be a potential threat under current conditions of rice husbandry.

Distribution of *Alisma lanceolatum* in the Coleambally Irrigation Area. The extent of the first population discovered in 1983 was mapped in detail and twelve farms were found to have been colonised by *A. lanceolatum*. Eighteen rice crops were infested to varying degrees and populations were also found in two drainage channels associated with the affected farms. This information is summarised in Figure 2 and Table 1.

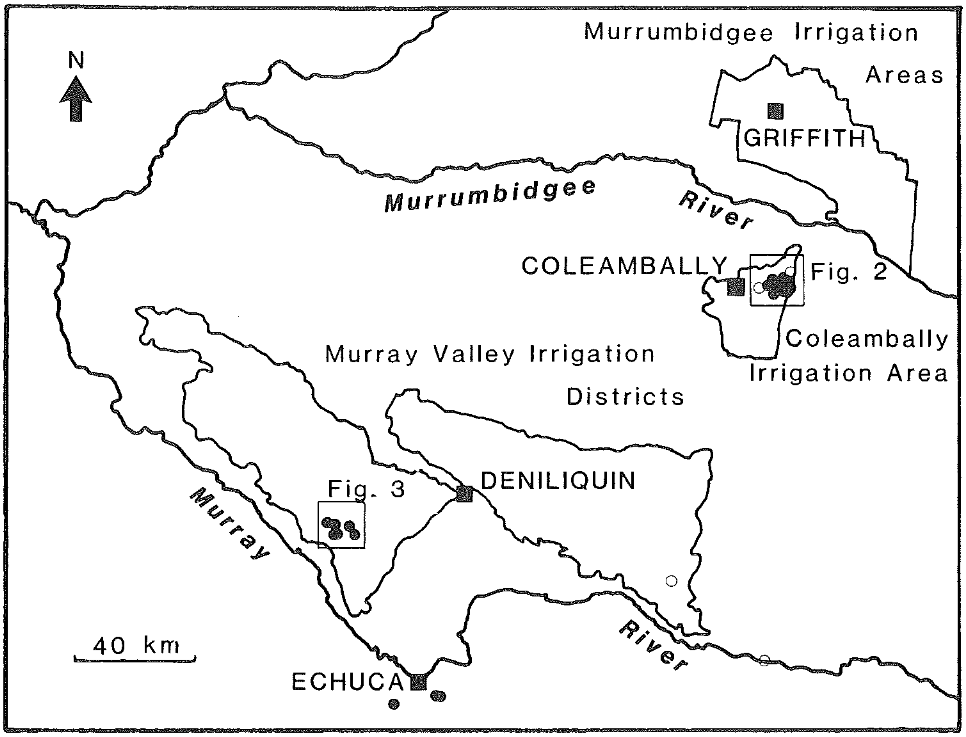

Figure 1. Distribution of *Alisma* spp. in the rice-growing areas of New South Wales, showing locations of collections of *A. lanceolatum* (●) and *A. plantago-aquatica* (○), January to March 1985.

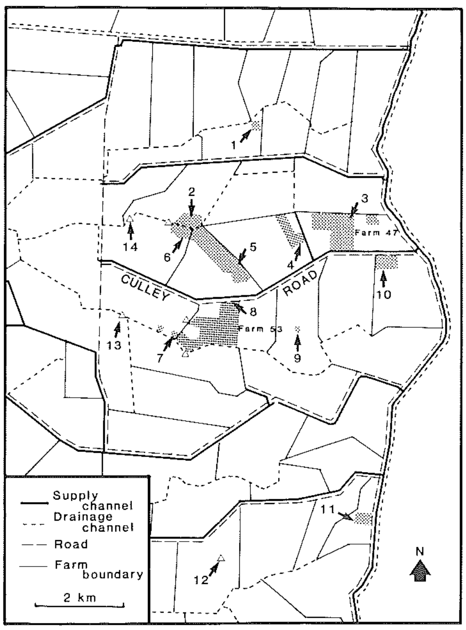

Figure 2. Distribution of *Alisma lanceolatum* in the Coleambally Irrigation Area, showing areas under rice where *A. lanceolatum* occurred (▒), locations of irrigation channel populations (△) and locations of collections (1–14) referred to in Table 1.

Table 1: Details of collections of *Alisma lanceolatum* from the Coleambally Irrigation Area, January to February 1985 (see Figure 2).

Map location number	Collection number	Habitat	Farm number	Population size (number of plants)	Comments
1	MNSM 366	rice crop	30	100–1000	throughout one bay
2	MNSM 358	rice crop	44	10–100	scattered through bay
3	MNSM 350	rice crop	47	1000–10 000	restricted mainly to borrow pits
4	MNSM 355	rice crop	48	100–1000	throughout bays
5	MNSM 356	rice crop	49	100–1000	throughout bays; spread to farm supply
6	MNSM 357	rice crop	50	100–1000	throughout bays
7	MNSM 361	rice crop	52	10–100	in borrow pits of four bays
8	MNSM 339	rice crop	53	>10 000	very severe infestation throughout
8	MNSM 348	rice crop	53	1000–10 000	severe infestation throughout
8	MNSM 338	on-farm supply channel	53	10–100	adjacent paddock infested but fallow
9	MNSM 360	rice crop	54	<10	in borrow pit, two small plants
10	MNSM 340	rice crop	56	100–1000	in crop and adjacent wet, fallow bay
11	MNSM 365	rice crop	96	10–100	throughout crop
12	MNSM 501	on-farm supply channel	99	<10	near uninfested crop
13	MNSM 346	drainage channel	—	<10	—
14	MNSM 352	drainage channel	—	10–100	—

The original infestation is thought to have been on Farm 47 or 53. Both properties were previously owned by the same person and now support considerable populations of *A. lanceolatum*, the largest in the area. There is no evidence of plants growing in supply channels leading to the infested area, suggesting that these farms support the founding population in the Coleambally I.A. The on-farm supply channels that did contain *A. lanceolatum* appear to have been colonised from populations in nearby rice crops. The rash of smaller infestations around these larger populations also appear to have arisen from short-distance dispersal.

Three occurrences of *A. lanceolatum* occur some distance away from the main infestation (Figure 2, sites 1, 11 and 12) and cannot be explained in terms of short-distance dispersal. In all three cases the use of agricultural machinery is strongly implicated in the spread of *A. lanceolatum*. Machinery from heavily infested farms has at some time been used on the land where the three satellite infestations occurred.

In addition to farm machinery, a likely cause of spread of *A. lanceolatum* in the future is the system of drainage channels leaving the affected area. These channels supported a small number of plants (<100) but they were large, well established and prolific producers of seed, which is readily carried downstream. At least one rice crop infestation (Figure 2, site 2) appears to have resulted from dispersal from an infested drainage channel.

***Alisma lanceolatum* in the Deniboota Irrigation District.** The infestation mapped in the Deniboota district was centred approximately 5 km south of Caldwell (Figure 3). Populations were discovered in two ditches, a rice crop and the associated drainage system (Table 2). The area between these locations and the nearest known *A. lanceolatum* at Echuca (40 km southeast) was searched, but no plants were found and it was clear that the Caldwell and Echuca infestations were disjunct.

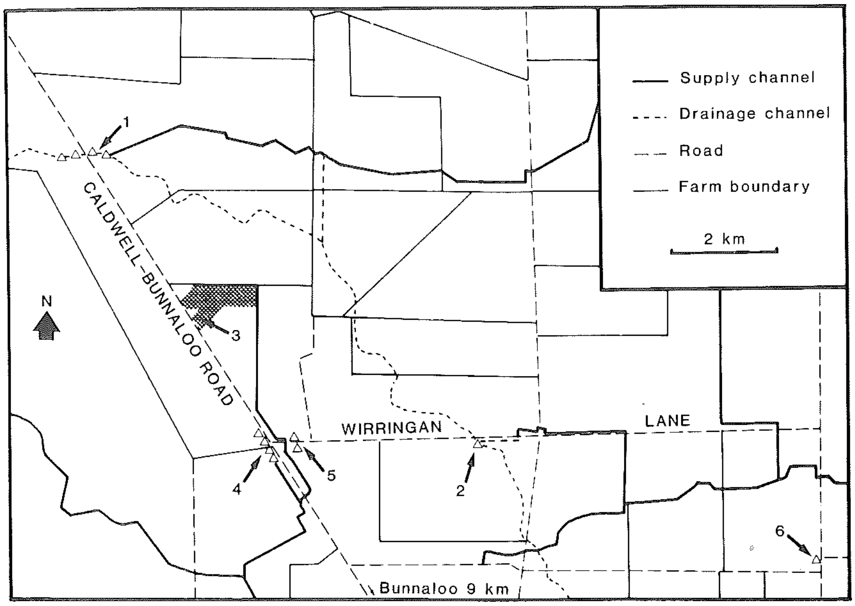

Figure 3. Distribution of *Alisma lanceolatum* in the Deniboota Irrigation District showing extent of populations in rice (▒), locations of populations in ditches and irrigation channels (△) and locations of collections (1–6) referred to in Table 2.

Although the six Caldwell populations are all likely to have arisen from one instance of long-distance dispersal (from Echuca, Coleambally or elsewhere), the founding population could not be identified. The largest infestation occurred in the affected rice crop, but here the large numbers of plants could have been a reflection of the extent of suitable habitat as much as an indicator of infestation age. Rice crops in this area are much more widely separated than in the Coleambally area, where rice fields are in close proximity. The fact that plants were found a considerable distance upstream of the infested crop, in the associated Deniboota Escape Channel, suggests that the rice field does not support the founding population.

The *A. lanceolatum* populations at Caldwell were isolated and scattered in comparison with the Coleambally distribution. The Caldwell infestation did not appear to be spreading on a front; future expansion is dependent on chance events and could occur in any direction. The only predictable direction of spread is downstream from existing populations growing in the Deniboota Escape Channel.

The scattered distribution of *A. lanceolatum* appears to be related to the low intensity of irrigation development in the Deniboota Irrigation District and the associated low density of suitable wet habitats. This situation, which is in contrast to that in the Coleambally area, is probably responsible for the lower number of affected rice crops in the Caldwell area (1 compared with 18 in the Coleambally I.A.). Given present land use in the Deniboota I.D., the rate of spread of *A. lanceolatum* amongst rice crops is likely to be slower than in Coleambally.

Table 2: Location, size and habitat of all populations of *Alisma lanceolatum* mapped in the Deniboota Irrigation District, January to March 1985 (see Figure 3).

Map location number	**Collection number**	**Habitat**	**Population size** (number of plants)	**Comments**
1	MNSM 515	drainage channel	10–100	downstream from infested rice crop
2	MNSM 520	drainage channel	1	upstream from infested rice crop
3	MNSM 517	rice crop	>10 000	growing throughout an aerially sown crop
4	MNSM 518	railway ditch	100–1000	area subject to foot traffic; seasonally wet
5	MNSM 519	roadside ditch	100–1000	growing with *Typha*
6	MNSM 521	intermittent watercourse	10–100	drains into Deniboota Escape (sites 1 & 2)

Sagittaria species

Sagittaria montevidensis

Sagittaria montevidensis is a native of North and South America where it is a weed of rice in California (Barrett & Seaman 1980) and Brazil and Uruguay (Gonzalez *et al.* 1981). Two subspecies have been introduced to Australia, ssp. *calycina* and ssp. *montevidensis*. Both are cultivated as ornamentals and the latter was recorded in Sydney in 1926 (Aston 1977; Sainty & Jacobs 1981). Subspecies *calycina* was first recorded in the Murrumbidgee Irrigation Area in 1962 and has spread rapidly in irrigation channels and rice fields. Although both subspecies are recorded for the Murrumbidgee I.A., it appears that only one, ssp. *calycina*, is widespread and ssp. *montevidensis* was not found in the region. The widespread Californian weed is also referable to ssp. *calycina* and has an annual life cycle. There are also reports of *S. sagittifolia* L. from the Griffith-Leeton district, but they are considered by Aston (1977) to be the result of confusion with *S. montevidensis*.

Since its introduction, *S. montevidensis* has spread southwards and is now also well established in the Coleambally I.A. (Figure 4). It occurs most frequently in drainage channels and rice crops. Recently, an isolated infestation was reported in the Tullakool I.A. This recording was the cause of some concern as it is the first known occurrence of this plant in the Murray Valley region.

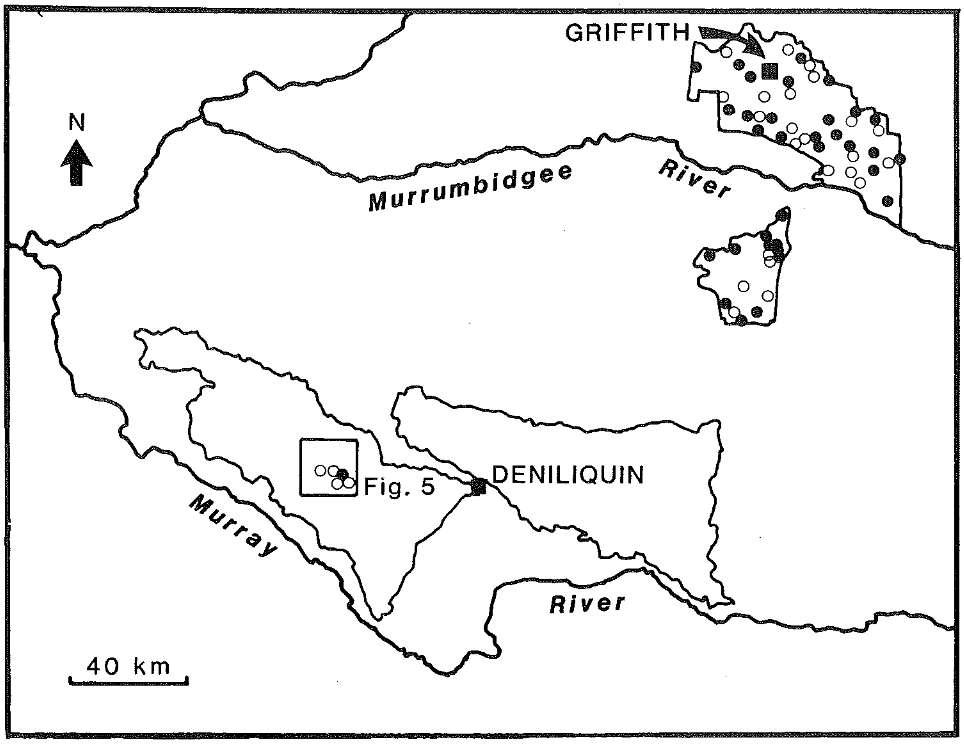

Figure 4. Distribution of *Sagittaria montevidensis* in the rice-growing areas of New South Wales, showing locations of collections from rice crops (●) and irrigation channels (○), 1984–85.

Table 3: Details of collections of *Sagittaria montevidensis* from the Tullakool Irrigation Area, January 1985 (see Figure 5).

Map location number	**Collection number**	**Habitat**	**Population size** (number of plants)	**Comments**
1	MNSM 418	drainage channel	1000–10 000	drainage from original infestation
2	MNSM 419	rice crop	10–100	3 bays affected along edge adjoining infested channel
3	MNSM 422	drainage channel	<10	flowing west along Burraboi Road
4	MNSM 423	drainage channel	10–100	in Niemur Drain at junction of Burraboi & Tullakool-Moulamein Rds
5	MNSM 424	drainage channel	10–100	tributary of Niemur Drain flowing west, bordering saltworks

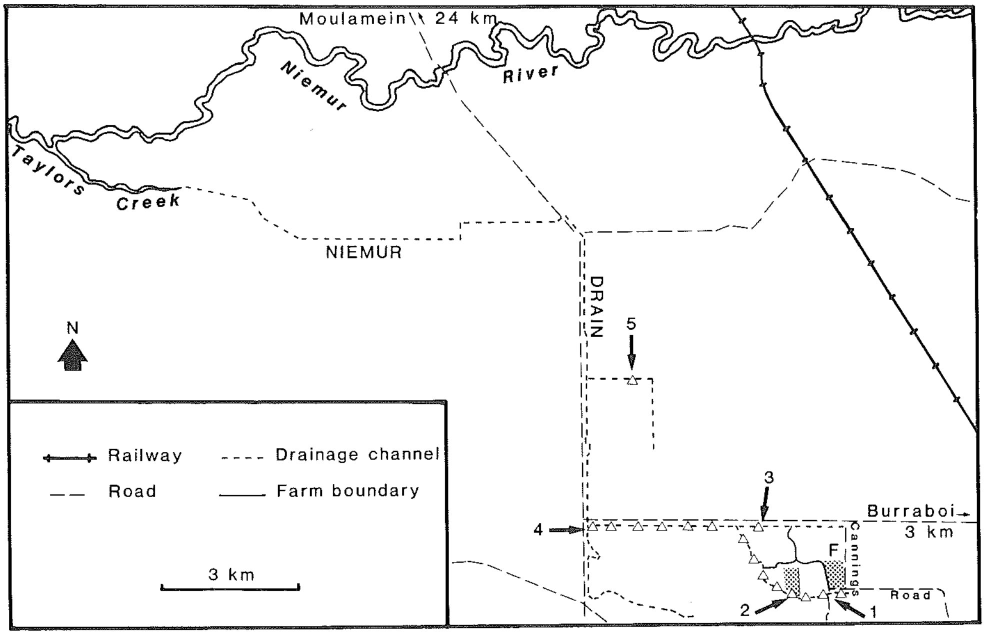

Figure 5. Distribution of *Sagittaria montevidensis* in the Tullakool Irrigation Area, showing extent of irrigation channel populations (△), locations of infested rice crops (▒) and collections (1–5) referred to in Table 3. F = field fallow in 1984–85.

***Sagittaria montevidensis* in the Tullakool Irrigation Area.** An infestation was reported in a rice crop in the Tullakool I.A. in the 1983–84 season. According to the grower, this introduction was the result of sowing contaminated seed. The seed used was from the Murrumbidgee I.A.

The site of the original infestation was fallow at the time of the survey, but *S. montevidensis* had spread into the associated drainage system and this area was mapped (Figure 5, Table 3). The extent of this infestation suggests that the original plants must have been introduced some years ago. *Sagittaria montevidensis* was found to occur sporadically along a 7 km stretch of drainage channel. The Water Resources Commission reported that a further 17.5 km of the Niemur Drain, as far as Taylors Creek, had been colonised but a vigorous spraying program has removed all evidence of these plants.

One rice crop adjacent to the infested channel was found to contain *S. montevidensis*. In this field, three bays were infested and plants were restricted to small clumps at the edge near the channel, suggesting that short-distance dispersal from the channel had occurred.

The introduction of *S. montevidensis* to the Murray Valley was probably inevitable, given the degree of population build-up in the northern irrigation areas. As suggested for *Alisma lanceolatum*, the rate of spread of *S. montevidensis* through the southern irrigation districts is likely to be slower than in irrigation areas, owing to the lower density of aquatic habitats.

Sagittaria graminea

A native of North America, *Sagittaria graminea* was introduced to Australia in the late 1950s and is now naturalised in Queensland, New South Wales and Victoria (Aston 1977). It is regarded as a troublesome weed in north-central Victoria where it obstructs water flow in drainage channels and creeks (Sainty & Jacobs 1981). *Sagittaria graminea* does not appear to be a significant rice weed elsewhere in the world.

Within the rice growing region, *S. graminea* is currently restricted to the Murray Valley where it seems to have entered as two separate introductions, both occurring as disjunct populations in the Berriquin Irrigation District (Figure 6). These are described below.

***Sagittaria graminea* in the Mulwala Canal.** *Sagittaria graminea* appears to have entered New South Wales from north-central Victoria via the Mulwala Canal which flows away from Lake Mulwala on the Murray River (Figure 7, Table 4). This canal is the main supply channel for the Berriquin I.D.

Lake Mulwala itself had been colonised by *S. graminea* and a 30 km stretch of the canal supported sporadic populations. Establishment was restricted to the canal banks where the water was shallow and slow-flowing. Intensive application of herbicides by the Water Resources Commission had limited the extent of the canal populations. Several branch supply channels were infested but plants have since been eradicated. Spot checking of rice crops and channels throughout the district indicated that no populations appeared to have arisen from the canal infestation. The chance of this happening in the future is probably high, but at present the infection pressure is limited as the number of plants in Mulwala Canal is low.

The 'Lindifferon' infestation. Large numbers of *S. graminea* were found on three adjacent holdings in the Berriquin I.D. near Deniliquin (Figure 8, Table 4). This population is over 40 km away from the Mulwala Canal populations.

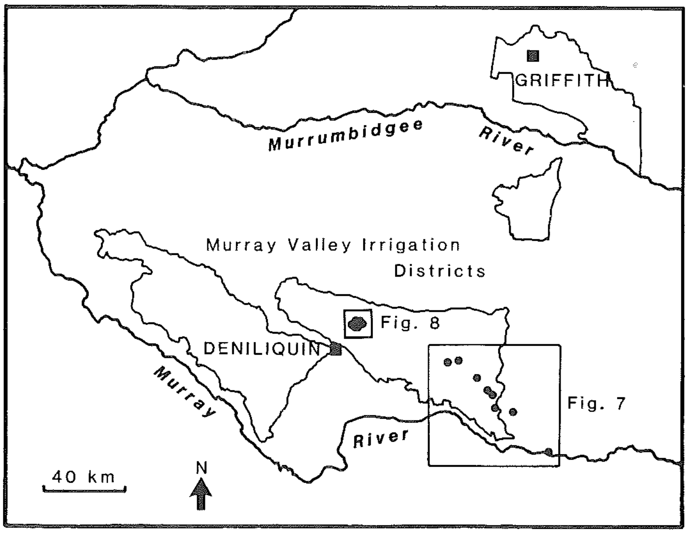

Figure 6. Distribution of *Sagittaria graminea* in the rice-growing areas of New South Wales showing locations of collection sites (●).

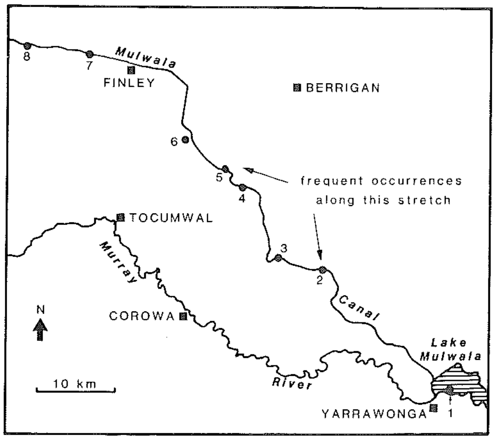

Figure 7. Distribution of *Sagittaria graminea* in the Berriquin Irrigation District, where it has colonized Mulwala Canal from a population in Lake Mulwala. Numbers (1–8) show locations of collections referred to in Table 4.

Table 4: Details of collections of *Sagittaria graminea* from the Berriquin Irrigation District, February to March 1985 (see Figures 7 & 8).

Map location number	**Collection number**	**Habitat**	**Population size** (number of plants)	**Comments**
1	MNSM 508	Lake Mulwala	10–100	much larger population (>1000 plants) near this collection
2	MNSM 576	Mulwala Canal	<10	broad-leaved plants growing in shade
3	MNSM 506	Mulwala Canal	1000–10 000	restricted to edge of canal which is very deep and wide
4	MNSM 510	Mulwala Canal	100–1000	as for 3
5	MNSM 511	Mulwala Canal	10–100	as for 3
6	MNSM 512	supply channel	10–100	close to point of departure from canal
7	MNSM 513	Mulwala Canal	10–100	as for 3
8	MNSM 514	supply channel	100–1000	50 m downstream from point of departure from canal
9	SM 1002*	supply channel	100–1000	growing throughout channel
10	SM 1003*	rice crop	1000–10 000	population extended to 3 adjoining rice crops
11	MNSM 586	supply channel	100–1000	broad-leaved plants growing in shade
12	MNSM 587	supply channel	100–1000	narrow-leaved plants growing in full sun
13	MNSM 590	supply channel	100–1000	growing throughout channel
14	MNSM 591	supply channel	100–1000	growing throughout channel
15	MNSM 592	rice crop	<10	restricted to borrow pit

* SM 1002 and SM 1003 were assessed for population size in 1985 but collected in May 1984.

On the property 'Lindifferon', a dam near an abandoned farmhouse supports large numbers (1000–10 000 plants) of *S. graminea*. The evidence available, including communications with farmers and the distribution pattern of the weed, indicates that the dam holds the founding population of *S. graminea*. It seems likely that the plant was introduced to the dam as an ornamental many years ago. Two adjacent properties, 'Box Lea' and 'Carmarthan', also support large populations.

On 'Lindifferon', *S. graminea* was limited to the dam, a rice crop and the supply channel between the dam and the crop. The rice crop on 'Box Lea' appeared to be free of the weed, although it grew in the farm supply channels. The third property, 'Carmarthan', was more seriously affected, with *S. graminea* growing in three rice crops and most of the supply channels. In the rice crops *S. graminea* was generally restricted to the borrow pits and areas of low rice plant density.

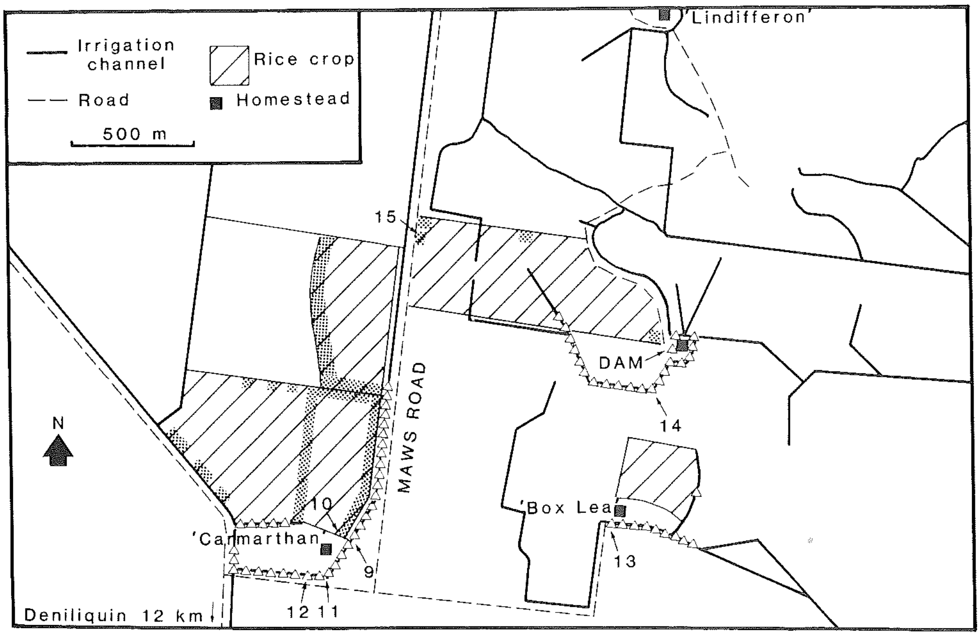

Figure 8. Distribution of *Sagittaria graminea* in the Berriquin Irrigation District, showing locations of populations in rice crops (▒), irrigation channels (△) and locations of collections (9–15) referred to in Table 4.

Damasonium minus

Damasonium minus is an annual plant which is endemic to Australia, where it is the most significant rice weed amongst the Alismataceae. The plant is widespread, but not particularly abundant in natural and seminatural wetlands (S. McIntyre, unpublished data). Plant numbers appear to have built up considerably in rice fields and *D. minus* began to be recognized as an important weed in the 1960s (Swain 1973), some 40 years after rice growing began.

Damasonium minus is widespread in all rice-growing districts; it was recorded at over 70% of sites in a survey of rice fields (McIntyre & Barrett 1985). Because of its abundance, no attempt was made to map *D. minus* and it can be considered ubiquitous in rice crops throughout the study area.

General Discussion

Several features of irrigation development ensure the spread of aquatic species. Plants are readily dispersed by water along the system of channels and spread efficiently over large areas. The movement of farm machinery and vehicles distributes soil, which may contain seed. These two methods appear to be the major dispersal mechanisms within irrigated areas.

Together, these factors make control of undesirable species difficult. Intensive herbicide programs such as those used against *Sagittaria graminea* in the Mulwala Canal and *Sagittaria montevidensis* in the Deniboota district have failed to eradicate these species. Eradication programs can probably only be successful for very small, isolated populations. As no systematic monitoring of weed populations occurs, introductions are often well established by the time they are noticed. Even rigorous monitoring could only be expected to reduce, not prevent, the establishment of new alien aquatic plants in the future.

Members of the Alismataceae have generally benefited from irrigation development. They are most abundant in drainage channels, rice crops and, to a lesser extent, in supply channels, wherever shallow water stands for prolonged periods. They do not often grow in transient wetland habitats such as roadsides and ditches.

The five species showed differing abilities to grow in various habitats. The newly introduced species may not yet have reached their potential range, but there are also differences in ecological characteristics.

Two of the five species appear to be serious competitors in rice crops. *Damasonium minus* is already a widespread, abundant weed, and *Alisma lanceolatum* has developed extremely high population levels within its current range. Interestingly, these species are the only ones to be recorded in ditches or roadsides and may be better adapted to intermittent flooding and high levels of disturbance.

Although widespread, *Sagittaria montevidensis* is not a particularly abundant rice weed in New South Wales, and tends to be restricted to borrow pits on the edge of rice bays. This is in contrast to the situation in California, where it is the most abundant weed of rice (Barrett & Seaman 1980). Such a discrepancy may be related to differences in land use patterns. Unlike *Alisma lanceolatum* and *Damasonium minus*, *S. montevidensis* has poorly developed seed dormancy (B. Cox, unpublished data) that prevents the accumulation of large reserves of viable seed in the soil. In situations where fields are continuously cropped, as is common in California, this characteristic is not a disadvantage because seed populations can be replenished annually. However, these plants would be vulnerable in New South Wales, where crop rotation is usually practised. Under these conditions, annual plants require a bank of dormant seed to survive fallow periods that are unfavourable to plant growth.

The comparative rarity of *Alisma plantago-aquatica* in the rice-growing region can not be explained. Its insignificance as a rice weed is also difficult to account for, especially in view of its importance in rice fields of Brazil, Chile and Europe.

Acknowledgments

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