Hymenachne

(*Hymenachne amplexicaulis*) in Queensland

PEST STATUS REVIEW SERIES - LAND PROTECTION

by
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1.0 Summary

Hymenachne (*Hymenachne amplexicaulis*) is a semi-aquatic perennial grass native to the seasonal, freshwater wetlands of South and Central America. It was released in Queensland in 1988 for use as 'ponded pasture'. Together with two other ponded pasture species, para grass and aleman grass, hymenachne is considered to be a valuable source of dry-season cattle fodder. Hymenachne continues to be planted in Queensland, the Northern Territory and Western Australia.

Reproduction occurs by seeds and from broken stem/stolon fragments. After being planted on grazing land, storm-water run-off has transported the plant's seeds and fragments into public waterways, irrigation storage facilities, sugar cane crops and natural wetlands where it is rapidly proliferating. Small infestations, generally between 0.5 - 100 ha in size, are scattered throughout coastal and sub-coastal areas of Queensland. The majority of naturalised stands originate from nearby grazing properties. To date, at least 1,000 ha have been invaded by hymenachne.

The plant is in its early stages of spread and has the potential to colonise much larger areas than currently exist. Based on climate modelling, hymenachne has the potential to grow within suitable habitats in coastal and sub-coastal freshwater wetlands of Queensland, probably extending into north-east New South Wales. The majority of problematic infestations are expected to be associated with river banks and freshwater, seasonal wetlands where there is a high influx of nutrients and sediments from upstream agricultural sources.

Continued spread of hymenachne is expected to impose substantial costs on the sugar cane industry by smothering young cane, contaminating "seed-cane" plots, impeding drainage and interfering with irrigation systems. There is little doubt that hymenachne will thrive in the highly disturbed, sediment and nutrient-rich drainage ditches and creeks that flow off sugar cane paddocks. The fishing industry is concerned that dense stands of hymenachne could degrade fishery habitats. Hymenachne is currently growing in close proximity to tropical freshwater wetlands with high conservation value. Conservation authorities fear that the plant will invade native plant communities within non-saline seasonal wetlands and affect dependent fauna.

Research is currently under way to identify suitable herbicides for hymenachne control. Preliminary results indicate that the most effective herbicide tested so far is Arsenal®. Arsenal is not currently registered for use on hymenachne. Repeated applications of Round-up Biactive®, combined with burning, can suppress the grass, but areas cleared of hymenachne will be continually re-invaded from other sites. A single application of Round-up is ineffective.

Soil moisture content (particularly during the dry-season), shade, duration and height of flooding and soil/water nutrient content appear to be important factors that affect the survival and abundance of hymenachne. The plant generally fails to persist in areas where the sub-soil dries out completely during the dry season. It is well adapted for survival in flooded areas and can withstand a maximum

flooding level of 1.2 m and 297 consecutive days of flooding. Clearing of native riparian vegetation combined with increased soil and nutrient run-off from crop land, especially land used to grow sugar cane, is creating ideal habitat for a range of exotic grasses, including hymenachne, para grass and aleman grass. Although hymenachne has adapted to survive in unpolluted tropical wetlands, it grows most vigorously in lowlands that are subject to run-off from crop lands (i.e. high nutrient and sediment loads). To some degree, dense growth of hymenachne is an indicator of poor land management.

Hymenachne offers an economic benefit to the central Queensland cattle industry. Despite this, expenditure required to control the plant in areas where it is not wanted, primarily in the 'wet tropics', will be substantial. It is impossible to accurately predict the plant's net benefit (or cost) to the State economy since it is impossible to predict either the total area of land that could be utilised as ponded pasture or the total area of land on which hymenachne will become an unwanted pest. Using the herbicide Arsenal, control costs for treatment of dense hymenachne are estimated to be between $652 and $688 per hectare. If eradication of unwanted hymenachne is attempted over large areas, the net impact of hymenachne on the State economy might be negative.

The negative impacts of hymenachne on the sugar cane industry, fisheries and the environment, highlight the need to review assessment protocols for new pasture releases and draw into question the economic justification for new ponded pasture species.

2.0 Taxonomic Status

The genus *Hymenachne* contains eight species distributed in tropical areas around the world (Bogdan 1977, Calder 1981).

Hymenachne amplexicaulis (Rudge) Nees, a native of South and central America, is distinct from *Hymenachne acutigluma* (Steudel) Gilliland, a native of northern Australian flood plains (Calder 1981) and *Hymenachne pseudo-interrupta* C. Muell. from the Indo-Malayan region (Bogdan 1977). In a number of publications, the name *H. amplexicaulis* has been misapplied to other congeners. For example, Blake (1954) misapplied *H. amplexicaulis* to *H. acutigluma*, as did White (1932) to Queensland specimens of *H. acutigluma*. Some land holders in Queensland believe that *H. amplexicaulis* and native hymenachne (*H. acutigluma*) are the same plant and they have difficulty understanding why people are concerned at the weed potential of *H. amplexicaulis*.

Hymenachne belongs to the family Poaceae and was first characterised by Rudge in 1805 as *Panicum amplexicaule* (Hill 1996). Synonyms include: *Agrostis monostachya* Poir; *Hymenachne myosurus* (Rich.) Nees; *Panicum amplexicaule* var. *deflexa* Doll; *Panicum amplexicaule* var. *erecta* Doll; *Panicum amplexicaule* Rudge; *Panicum hymenachne* Desv.; *Panicum perdensum* Steud.; *Hymenachne pseudo-interupta* (Li 1978); *Hymenachne myurus* (Howard 1979).

The cultivar of *H. amplexicaulis* approved by the Herbage Plants Liaison Committee for release in Queensland in 1988 was named 'Olive'. Hence, some literature refers to the plant as 'olive hymenachne' and this is the name commonly used in the Northern Territory to differentiate it from native hymenachne. Other common names include 'West Indian marsh grass' (Florida), 'bamboo grass' and 'dal grass'.

2.1 Description

Hymenachne is a robust, stoloniferous, perennial grass commonly 1 - 2.5 m tall (Fig. 1). It grows rooted in the substratum and its stems float out into deep water. The glabrous stems are erect or ascending from a prostrate base and are filled with white pith (aerenchyma). Roots are produced from the lower nodes. Leaf blades are 10 - 45 cm long and up to 3 cm wide, mostly lanceolate and cordate at the base. They are markedly narrower in the upper half. Ligules are membranous. The panicles are narrow, spike-like, cylindrical, 20 - 40 cm long, sometimes with two or more long upright branches. Spikelets are lanceolate, upright and 3 - 5 mm long (Bogdan 1977, Cabrera 1970).

Fig. 1. Growth habit of hymenachne (*Hymenachne amplexicaulis*) (photo: P. Van Haaren).

Flowering culms are 80 - 95 cm tall, sparingly branched, with up to 4 nodes. Primary branches of the panicles have spreading secondary branches, 0.5 - 2 cm long, and are scabrous on the margins. Pedicels are 0.2 - 1 mm long with disarticulation at the base of the spikelet. Spikelets are dorsiventrally compressed, linear-lanceolate, 3 - 4 mm by 0.6 -0.8 mm. Lower glumes are 1.5 - 1.8 mm long, triangular, 3-nerved, hyaline, smooth, glabrous, acute. Upper glumes are 3 - 4 mm long, linear-lanceolate, 5-nerved, hyaline, glabrous, long acuminate. The lower floret is neuter; lower lemma 3 - 4 mm by *c*. 1 mm, linear-lanceolate hyaline. Upper floret is hermaphrodite; upper lemma 2.5 - 3.5 mm long, white, hyaline, smooth, lanceolate, glabrous, acute; upper palea hyaline, smooth, not enclosed at the apex by the lemma (Wildin 1989a). The plant employs the C3 photosynthetic pathway and has a chromosome number: 2n=24 (Watson and Dallwitz 1992).

2.2 Distinguishing characters

H. amplexicaulis is similar to *H. pseudo-interrupta* C. Muell. in habit and floral parts. However, the leaves of the latter are narrower, linear to linear-lanceolate and are not cordate at the base (Bogdan 1977). *H. amplexicaulis* can be distinguished from other species by its characteristic stem-clasping leaf bases (Fig. 2). *H. amplexicaulis* is considerably larger and more robust than para grass (*Brachiaria mutica* Stapf.), which often grows near stands of *H. amplexicaulis*.

Fig. 2. Distinctive stem-clasping leaf of hymenachne (*Hymenachne amplexicaulis*) (photo: S. Csurhes).

3.0 History of Introduction and Spread

Hymenachne was imported in the early 1970's, together with another ponded pasture species, aleman grass (*Echinochloa polystachya* cv. Amity) (CSIRO 1973). A cultivar of hymenachne, referred to as CPI 61149 and labelled as *Eriochloa imbricata*, was received from the International Research Institute, Tucupita, Venezuela, and is believed to have originated from either Haiti or the Dominican Republic (Wildin 1989a). The Queensland Department of Primary Industries tested the plant for use as 'ponded pasture' in water too deep for para grass (*B. mutica*). Initial planting occurred on grazing properties in Central Queensland. One of these properties was 'Granite Vale' near St Lawrence, the property of J. and P. Olive (hence the cultivar name 'Olive').

In August 1988, hymenachne and aleman grass were approved for release by the Queensland Herbage Plant Liaison Committee which recommended registration on the submission of the Queensland Department of Primary Industries (Wildin 1989a, 1989b). Following official release, land holder interest in ponded pastures increased rapidly, as did the adoption rate (Wildin *et al*. 1996a). Several field days organised by the Queensland Department of Primary Industries promoted hymenachne as a desirable forage plant and graziers were quick to obtain vegetative material and hand vegetative material to friends, not only in Queensland but interstate. Prior to release of these plants, ponded pasture systems relied on native grasses and the introduced para grass (*B. mutica*), the latter being intolerant of water deeper than 60 cm.

Hymenachne first came to the attention of cane farmers in the late 1980's, soon after it had escaped from pastures and naturalised in the 'Red Lily Lagoon' area of the Lower Burdekin, coastal north Queensland (Schultz 1997). This was possibly the earliest report of the plant becoming naturalised in Queensland. At that time, several graziers were planting hymenachne into natural and artificial pondage areas in the Giru, Clare and Lower Burdekin areas. Until 1996, the plant was generally confined to areas where it had been planted and did not appear to pose a serious threat to sugar cane crops. In 1996 an infestation was noticed in the Haughton Balancing Storage dam and small clumps appeared in 'Pink Lilly Lagoon' in the Haughton area. Early in 1997, a severe infestation appeared in sugar cane on a Haughton district farm. Cane field infestations were also reported near earlier plantings at Clare. In 1997, the Invicta Cane Protection and Productivity Board commissioned an aerial survey of the Invicta cane growing area and its surrounds. The survey revealed extensive infestations in coastal wetlands in the Giru area and in the Burdekin River Irrigation Area (BRIA). Additional infestations were found at the Burdekin Agricultural College, on two farms in the Mulgrave area of the BRIA, the Mulgrave balancing storage dam, in irrigation supply channels downstream of the Haughton balancing storage dame, in the Selkirk riparian zone and in a lagoon behind Dalbeg in the Upper Burdekin area (Schultz 1997). In 1997, a series of north Queensland newspaper articles expressed concern at the propensity for hymenachne to become a destructive pest in sugar cane. The Queensland Environmental Protection Agency first raised concerns regarding the plant's propensity to invade natural wetlands in the late 1980's (J. Clarkeson, *pers. comm*. 1998).

4.0 Current and Predicted Distribution

4.1 Distribution - overseas

H. amplexicaulis grows naturally in seasonally flooded lowlands and along river banks throughout tropical and sub-tropical areas of South and Central America (Bogdan 1977). The Missouri Botanical Garden's 'TROPICOS' data base gives the plant's general distribution as: Argentina, Belize, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, French Guiana, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Peru, Paraguay, Surinam, Uruguay, Venezuela and the West Indies (Anon. (a) 1997). This area lies between the northernmost herbarium record of the plant at Tabasco, Mexico (latitude 19^0N) and the southernmost record in southern Paraguay (28^0S) (approximate latitudes). Naturalised populations in southern Florida lie near latitude 26^0N.

At some locations within its native range, hymenachne has formed dense, pure stands. Of some five million hectares of flooded lowlands in Venezuela, at least 20 % of this area is dominated by hymenachne (Gonzalez-Jimenez and Escobar 1977). Elsewhere within its range, the plant's abundance varies depending on edaphic and climatic factors including depth of flooding, period of inundation and depth of the watertable during the dry season. In the Peruvian Amazon, hymenachne is a component of flooded grasslands, known locally as 'pantanal' (Kalliola *et al*. 1991).

4.2 Distribution - Australia

In 1995, some 26,000 ha in Queensland were being utilised as ponded pasture (Weier *et al*. 1995). However, most of this area contained para grass and it is not known what percentage was occupied by hymenachne. In 1991, at least 21,800 ha of ponded pastures existed in Central Queensland, with some 11,900 ha on 170 grazing properties in the Local Government areas of Broadsound, Livingstone and Fitzroy (Table 1) (Cummins 1991). Most of these pondage schemes comprised relatively small areas with only about 20 land holders having ponded areas over 100 ha (Cummins 1991).

Table 1. Area of constructed ponds in central, coastal Queensland (at 1.12.1990) (Cummins 1991).

Shire	Area of constructed ponds (ha)
Broadsound	1,300
Livingstone	7,000
Fitzroy	3,600
Calliope	200
Banana	3,500
Duaringa	1,550
Belyando	3,650
Nebo	200
Pioneer	250
Sarina	550
Total	21,800

Presently para grass is favoured for these ponded areas but other grasses like hymenachne and aleman grass could replace or complement para grass. Outside ponded areas on grazing properties, the plant has naturalised at several hundred locations scattered throughout coastal areas of central and northern Queensland. As part of this study, Local Governments were surveyed to assess the number and approximate size of naturalised populations of hymenachne in coastal and sub-coastal central and northern Queensland. This information was supplemented by reports received from officers employed by the Departments of Natural Resources, Environment, Primary Industries as well as people employed within the sugar cane industry. This information is summarised below and presented in Fig. 3.

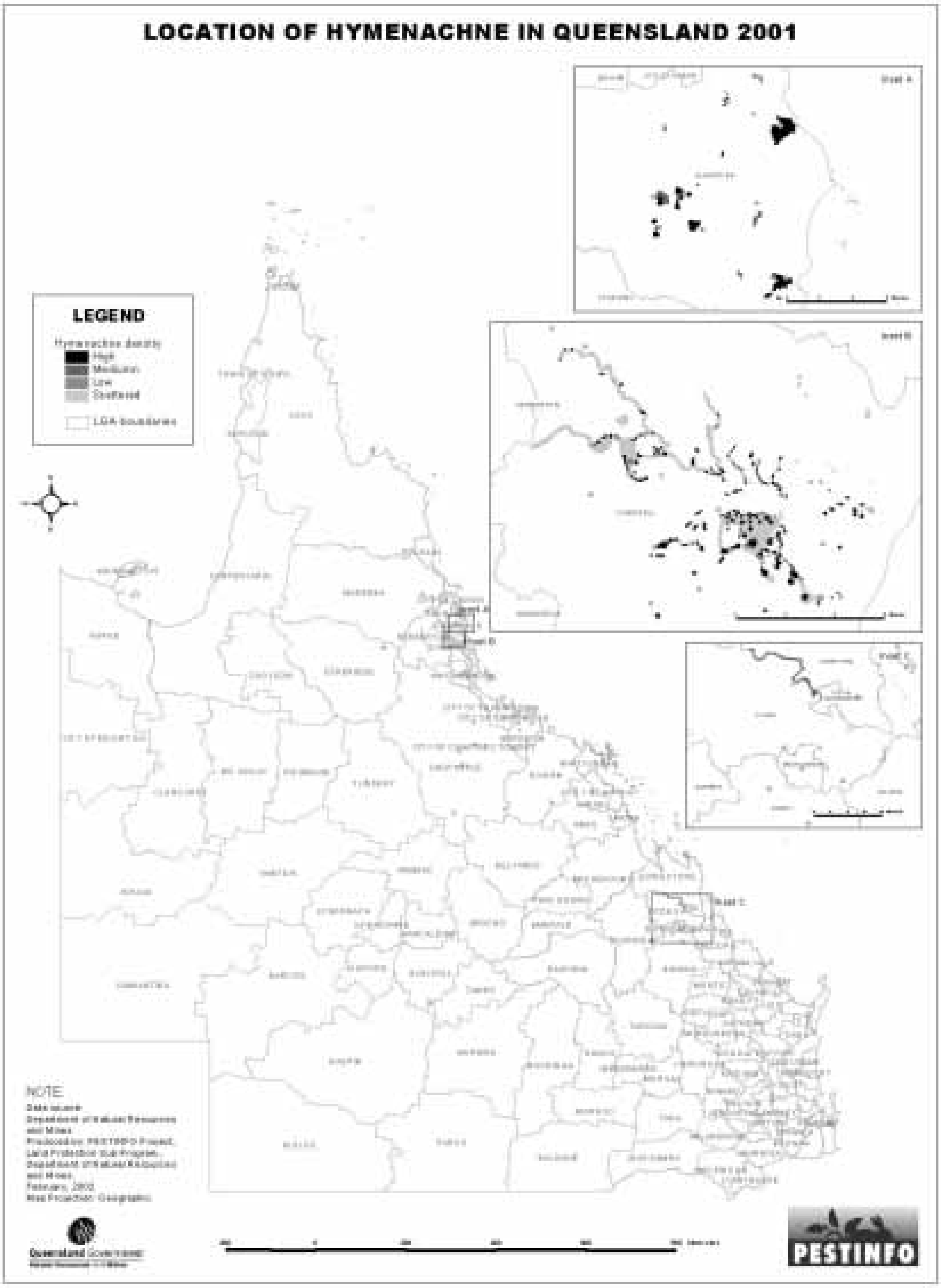

Fig. 3. Distribution of hymenachne (*Hymenachne amplexicaulis*) in Queensland.

Wet Tropics:
The plant exists in all catchments along the wet tropical belt (James 1997). Low (1997) estimates that the plant has invaded 1,000 ha of land in the wet tropics.

Cairns City: A dense infestation covering some 5 ha exists along Dinner Creek approx. 12 km south-west of Bramston Beach and originates from a nearby ponded pasture. This infestation is of concern since the creek flows into Eubanangee Swamp National Park, an area of high conservation value. A further *c*. 5 ha has been planted as ponded pasture 2 –4 km north-east of Babinda and *c*. 5 ha are infested with hymenachne in ponded pasture and cane drains 7 km north of Babinda. Some cane crops nearby have been ploughed out in an attempt to remove hymenachne. A 0.5 ha area has been planted for ponded pasture in natural depressions 2 - 3 km south-west of Bellenden Ker (R. Luxton, D. Assenbruck, R. Edwards, W. Price, B. Brand, P. Thompson, G. Bugeja, N. Clarke and L. Phillips *pers. comm.* 1998).

Within the Barron River catchment (near Cairns) a small infestation (*c*. 3 - 5m^2) has been reported along Spring Creek (G. Hardwick, *pers. comm.* 1998). Infestations also exist along the northern margins of the catchment within the Rifle Creek sector of the Mitchell system.

Johnstone Shire: Approximately 20 ha are infested at South Maria Creek, 4 - 5 km north-west of Bingil Bay. The plant was originally planted for ponded pasture but now infests cane, drains and lowlands in this area. Additional infestation sites include, *c*. 1 ha 3 - 4 km north of Warrubullen, *c*. 2 ha planted in ponded pasture 7 - 8 km south of Flying Fish Point where it has colonised nearby creek systems and other low depressions, *c.* 1 ha planted 4 km west of Flying Fish Point where it has colonised ex-pasture and creek systems, *c*. 1 ha planted in a swampy area 1 km south-west of Shaw's Corner, *c*. 3 ha approximately 4 km south-west of Mena Creek, again originally planted as ponded pasture but now escaping into a nearby creek. Scattered, small infestations (*c*. 2 ha each) are located 8 - 10 km south west of Mena Creek (R. Luxton, D. Assenbruck, R. Edwards, W. Price, B. Brand, P. Thompson, G. Bugeja, N. Clarke and L. Phillips *pers. comm.* 1998).

Cardwell Shire: Infestations include *c*. 42 ha of scattered stands associated with the banks and floodplains of Echo Creek and Davidson Creek, tributaries of the Tully River, *c*. 15 ha of scattered infestations along the banks and in the floodplains of the Tully River upstream from Echo Creek (includes Tully River Station), *c*. 1 ha in drains and low depressions approximately 3 km south of where the Bruce Highway crosses the Murray River, *c*. 30 ha in cane drains, low depressions and roadside ditches along the banks of the Murray River west of where the Bruce Highway crosses the Murray River, *c*. 4.5 ha at two separate locations along the upper reaches of the Murray River, *c*. 14 ha of scattered infestations south of the Murray River along creek banks, in depressions and drains (some planted as ponded pasture). One large (10 ha) area exists on "Wallacevale" (originally planted as ponded pasture), *c.* 2 ha at Barrett's Lagoon and a further 17 ha of scattered infestations south of the mouth of the Tully River (a *c*. 2 ha area is being controlled by staff from the Queensland Parks and Wildlife Service) (R. Luxton, D. Assenbruck, R. Edwards, W. Price, B. Brand, P. Thompson, G. Bugeja, N. Clarke and L. Phillips *pers. comm.* 1998).

To date, hymenachne is yet to invade Edmund Kennedy National Park, south of Tully. However, the plant is abundant further upstream in the Murray River which flows through the park. Some 2,500 ha of freshwater wetlands within the park are considered to be ideal habitat for hymenachne and are at risk of invasion (W. Price, Park Ranger, *pers. comm.* 1999). Since, hymenachne has been planted on “Wairuna Station”, a cattle property at the headwaters of the Burdekin River, floodwater are expected to carry the plant downstream.

Hinchinbrook Shire: Infestations include: a *c*. 3 ha infestation along the banks of a creek some 8 - 9 km north of Ingham, *c*. 11 ha of scattered infestations in a lagoon near Bambaroo, *c*. 17 ha of scattered infestations along Cattle Creek (approx. 11 - 12 km south of Ingham), where it has invaded natural lagoons and sedgeland, *c*. 6 - 8 ha of solid hymenachne in a lagoon approx. 1 - 2 km south of Ingham, *c*. 80 ha of scattered infestations with some heavy infestations on a floodplain associated with Palm Creek approximately 15 - 18 km east of Ingham, *c*. 0.5 ha infestation approximately 1 km north of the Herbert River, about 12 km north-west of Ingham (where it was planted as ponded pasture) and two infestations (*c*. 0.5 ha each) in drains near Stone River approx. 20 km west of Ingham (where it is subject to regular control attempts) (R. Luxton, D. Assenbruck, R. Edwards, W. Price, B. Brand, P. Thompson, G. Bugeja, N. Clarke and L. Phillips *pers. comm.* 1998). Following several years of promotion as a ponded pasture, additional infestations undoubtedly exist elsewhere in the ‘wet tropics’.

Wet-dry Tropics:

Mareeba Shire: To date, six small infestations (each 2 - 3 ha) have been recorded in the Shire. These probably originated from material planted for ponded pasture (P. Davis *pers. comm.* 1998). A small area of hymenachne is currently maintained by QDPI at its Mareeba centre within 500 m of the Barron River (G. Hardwick, *pers. comm.* 1998).

Thuringowa City: None reported (P. Murray, *pers. comm*. 1998).

Townsville City: Of concern is an infestation in the “reed beds” which is a wetland area upstream of one of Queensland’s Ramsar sites; Bowling Green Bay near Townsville (RAMSAR Site 42 - internationally acclaimed wetland habitat). The Ramsar site is an area of 35,500 ha with 32,100 ha within the Bowling Green Bay National Park with the remainder of the site being held under various tenures. At least 30 ha of hymenachne exist within the Park’s catchment (James 1997).

Burdekin Shire: Hymenachne has existed in the Burdekin Shire since 1995, where it was first discovered in drainage systems associated with the North Burdekin Water Board area. A grazier is reported to have planted the first hymenachne in the region to provide cattle feed. The plant was also growing at around the same time on another grazing property adjacent to the Bruce Highway at the downstream end of the Healey’s Lagoon system (James 1997). Eleven infestation sites have been mapped within the Burdekin River Irrigation Area (BRIA) with the largest infestation (*c*. 100 ha) occurring in the Haughton Balancing Storage recharge system. This infestation was sprayed with herbicide in October 1997 and is under active control by the Queensland Department of Natural Resources and Mines. It also exists in aquifer recharge channels as well as artificial and natural drainage depressions within the BRIA (James 1997).

Dalrymple Shire: Hymenachne was first planted at Swan's lagoon near Charters Towers (date unknown). Infestations and ponded pasture plantings include: a 20 m diameter patch of hymenachne in a roadside ditch at "Dotswood" army training grounds on the northern side of the Mirambeena Road (origin unknown), small patches of hymenachne planted as ponded pasture on "Mirtna" approx. 140 km south of Charters Towers, a small patch at Powlathanga Lake on "Powlathanga" some 38 km south-west of Charters Towers (where the property owners are experiencing trouble getting the plant to grow), small patches along the Sutter River approx. 140 km south-east of Charters Towers, *c*. 100 ha scattered across ponds on "Wambiana" approx. 45 km south-west of Charters Towers (drought and cattle reduced it from an original size of *c*. 400 ha) (P. Horrocks, B. Shepard, P. Jefferey *pers. comm.* 1998).

Croydon Shire / Etheridge Shire: Several years ago there were one or two stands of hymenachne in Croydon Shire and Etheridge Shire. However, due to seven years of drought and severe overgrazing most is now dead (P. Horrocks *pers. comm*. 1998).

Central Queensland Coast:
Hymenachne has been planted in most ponded pastures around Rockhampton, although recent "drought" has slowed its establishment. It is proliferating rapidly in creek systems in the Rockhampton area (Dunlington *pers. comm.* 1998). Creeks such as Belmont Creek were once open waterways but are now completely choked by hymenachne. A particularly dense mass exists in Lion Creek, adjacent to the entrance of the creek into the Fitzroy River. Scattered infestations of some 10 - 20 ha in size exist along the Fitzroy River and its tributaries (C. Jones, *pers. comm.* 1999, P. Hinchliffe, *pers. comm.* 1998, R. Black *pers. comm*. 1999). Upstream of the Fitzroy River barrage, hymenachne can be found along both banks of the Fitzroy River for a distance of some 15 - 20 km and covers at least 100 ha (C. Jones, *pers. comm.* 1999, J. Barrie *pers. comm*, 1999). A significant infestation covering an estimated 25 - 30 ha exists within, and adjacent to, the proposed Angle Island Environmental Reserve, a natural wetland area some 20 km north-west of Rockhampton (R. Black, *pers. comm.* 1999). Additional sites include Nankin Creek (*c*. 5 m^2 infestation originating from adjacent grazing property), Limestone Creek near Yeppoon (*c*. 300 m x 10 m wide infestation), Scrubby Creek, Alligator Creek and Corduory Creek (L. Childs, D. Ballantine, Livingstone Shire Council, *pers. comm.* 1999).

Central Highlands / West Region: There are no records of the plant in this region (D. Akers *pers. comm.* 1998).

South-east Queensland:
A recent survey covering approximately 150 km along the banks of the Burnett River (upstream of Bundaberg) found that hymenachne exists as scattered infestations along some 40 km of the river. Scattered infestations also exist elsewhere in the Burnett and Miriam Vale Local Government areas (B. Shore, *pers. comm*. 1999). No infestations have been reported south of Bundaberg.

Other States:
Hymenachne has naturalised in the Northern Territory where it has been promoted as a ponded pasture grass. It has been suggested as a replacement for *Mimosa pigra*. In 1993, hymenache and aleman grass were estimated to cover 250 ha in the Northern Territory (Stockwell *et al.* 1996). This compares to some 8,000 km^2 of floodplains in the Northern Territory (Wilson *et al.* 1990) which are dominated by native hymenachne (*H. acutigluma*).

4.3 Potential distribution in Australia

Climate, water depth, period of inundation, soil moisture (especially during the dry-season), percentage shade, salinity and soil-water nutrient status are important factors that will govern the plant's potential distribution and abundance. Hymenachne can survive prolonged inundation (up to 297 consecutive days in water 1.2 m deep) (Tejos 1980) but can only grow along the edges of permanent deep water. The plant does not persist in estuarine or brackish wetlands and its abundance declines sharply as the frequency of salt-water intrusion increases (G. Blackman, *pers. comm*. 1999). Since light availability is considered to be a primary factor limiting macrophyte distribution and abundance (Canfield and Hoyer 1988), hymenache is not expected to form extensive stands where native trees shade the banks of watercourses. Hymenachne is predicted to become most abundant in seasonal freshwater wetlands that are subject to influx of sediments and nutrients from upstream agricultural land. To some degree, the plant is expected to become an indicator of polluted or otherwise disturbed wetlands, much like para grass. Factors that influence survival and growth of hymenachne are discussed further in section 6.1.

After studying information on the plant's natural habitat and distribution in North, Central and South America (where its range extends between latitudes 26^0N and 28^0S), it is predicted that hymenachne will persist as a component of tropical and sub-tropical freshwater marshlands and the banks of lowland watercourses throughout coastal Queensland. It is expected to become most abundant in seasonally-flooded marshlands in tropical areas, especially nutrient-enriched sites, but will also persist in the sub-tropical zone, at least as far south as 28^0S (northern New South Wales). The plant could spread into sub-coastal, tropical areas and perhaps into the semi-arid zone wherever land is flooded during the wet season and where the soil is reasonably high in nutrients and remains waterlogged during the dry season. Within inland regions, suitable conditions for hymenachne could be created on clay soils by irrigation or by artificial or natural banks that trap overland water flow. The plant is not expected to persist on well-drained soils.

Climate analysis, using the "CLIMEX" computer modelling package (Skarratt *et al*. 1995), suggests that climates experienced in coastal areas of northern Australia are similar to those experienced in the plant's native range (Fig. 4). As such, hymenachne has the potential to colonise suitable habitats over much of coastal, northern Australia.

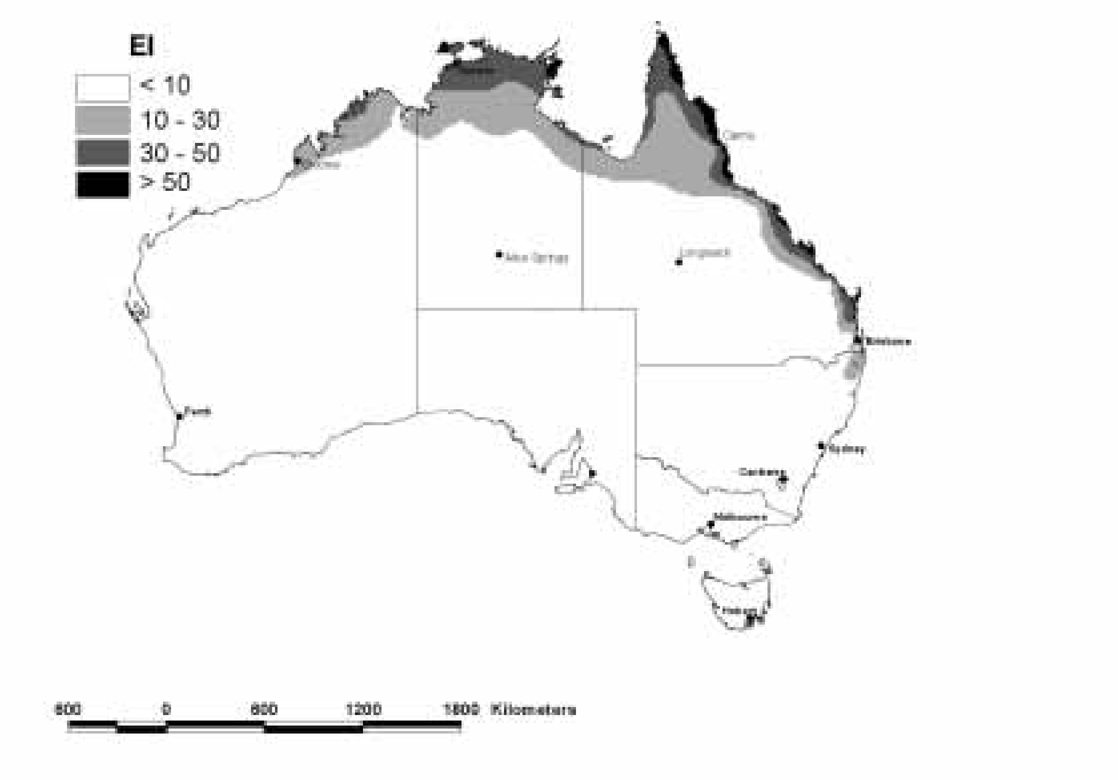

Fig. 4. Potential distribution of *Hymenachne amplexicaulis* generated by "CLIMEX".

Para grass is estimated to cover 100,000 ha of swampy land in Queensland (Walker and Weston 1990) and 40,000 ha in the Northern Territory (Low 1997). The total area currently occupied by para grass may provide a crude indication of the potential distribution of hymenachne, since the two species have similar habitat requirements and climatic preferences. There are, however, important differences between the two species. Firstly, hymenachne is taller than para grass, and can tolerate water almost twice as deep (Oram 1990). As such, it has the potential to smother para grass in many areas and extend into deeper water. In fact, in several creeks near Rockhampton, hymenachne has already replaced para grass and has produced dense floating mats that extend 4 – 6 m out from creek banks, compared to 1 - 2 m for para grass (J. Barrie, *pers. comm.* 1999). Secondly, para grass is a C4 species, whereas hymenachne employs the C3 photosynthetic pathway. C3 grasses generally have poor water use efficiency and in some wet-dry tropical habitats might be less competitive than C4 grasses (P. Pittaway, *pers. comm*. 1999).

5.0 Estimates of Current and Potential Impact

5.1 History as a weed overseas

Holm *et al*. (1979) listed hymenachne as a weed in Surinam, Indonesia and Trinidad. In Trinidad, it has become a major weed in rice and exists in most swamps (Mason 1993). Over the past two decades, hymenachne has been invading the wetlands of Florida (Haller 1997). In 1997, it was included in the Florida Exotic Pest Plant Council's 'List of Florida's Most Invasive Species' as a 'Category 1' species (i.e., one that is invading and disrupting native plant communities in Florida) (Anon. (b) 1997).

5.2 Current and potential impact in Queensland

5.2.1 Sugar industry

Hymenachne is beginning to have an impact on the north Queensland sugar industry, an industry worth $A1,146M in 1995/96. Infestations have been found in cane paddocks, drainage/irrigation channels and water storages that supply irrigation water to cane farms. In some situations, hymenachne can decrease cane productivity through direct competition, reducing final returns. For example, Van Rossum (1997) reported an instance where hymenachne contamination reduced a cane farmer's return from $55/t to $30/t of harvested cane. Returns were reduced to zero for a Babinda cane grower, who "ploughed-in" two hectares of infested cane. Another farmer lost $21,775 when his 10 ha "seed-cane" plot was condemned for use as "plant-cane" due to the presence of hymenachne (N. Beattie, *pers. comm.* 1997) (Fig. 5). A cane farmer in the Burdekin region is reported to have spent $17,000 trying to eradicate hymenachne from his cane paddocks (P. James, *pers. comm.* 1997). Similarly, two cane farmers near Ingham have spent $20,000 over the last two years on control of hymenachne. Good drainage is vital on most cane farms situated on flat, coastal floodplains. Many cane farmers in north Queensland fear that hymenachne will "choke" drainage systems and cause increased flooding and loss of low-lying cane crops. Some cane farms currently suffer losses of $80,000 - $100,000 per annum due to poor drainage. These losses are expected to increase substantially if drainage is impeded by dense stands of hymenachne (J. Irvin, *pers. comm*. 1999).

Fig. 5. Hymenachne growing on sugar cane land, Babinda, North Queensland (photo: P. Van Haaren).

Mr Lyons, Chairman of the Invicta Cane Protection and Productivity Board has commented that "the plant is vigorous enough to compete with the crop, especially in areas prone to waterlogging. Heavy infestations will not allow clean burns and can be expected to cause considerable harvesting problems. Vigorous stands of the plant will grow through the (cane) canopy" (Schultz 1997).

Drainage channels choked by aquatic macrophytes inevitably become sites of sediment deposition, reducing the effective channel capacity (Humphries *et al.* 1994, Smith *et al*. 1995). These hydrological and morphological changes substantially increase the incidence of floods, which translate into a significant economic cost to cane farmers through erosion of soil and direct loss of crops (Bunn *et al*. 1998). Cane farm maintenance costs could increase due to the requirement to keep irrigation and drainage channels free from hymenachne. According to cane farmers, irrigation equipment needs more regular servicing and filter costs will increase. On infected properties, more time is needed to wash down machinery used in contaminated areas. Where hymenachne becomes established within stored irrigation water it can be inadvertently spread onto non-infested paddocks over a large area. Of concern are a number of infestations within irrigation facilities in the Burdekin district, a major sugar cane production area. At the very least, infestations are expected to impede the flow of irrigation water in channels, increase pumping costs and increase water loss between storage facility and farm.

Although impacts on the sugar industry are currently localised, the plant is in its very early stages of spread and many cane farmers are concerned at the plant's long-term impact on their livelihoods. Some cane farmers rank hymenachne as their worst weed. There is little doubt that hymenachne will thrive in the highly disturbed, sediment and nutrient-rich drainage ditches and creeks that flow off sugar cane paddocks.

5.2.2 Water resources

Some irrigation water storage facilities operated by the Department of Natural Resources and Mines are contaminated with hymenachne, necessitating expensive control operations (approximately $200,000 has been allocated to the short-term control of hymenachne in a single facility). Infested facilities will need to be re-treated on a regular basis if they are re-invaded by broken fragments of hymenachne washed in from upstream sources. Hymenachne has the potential to invade many more water storage facilities throughout coastal and sub-coastal areas of Queensland.

Dense swards of hymenachne can impede the flow of flood water, perhaps causing increased flooding of low-lying areas. In addition, floating mats of hymenachne have been reported to block drainage infrastructure near Cardwell, north Queensland (Anon. (c). 1997). Rockhampton City Council has expressed concern at the risk posed by hymenachne to Council's potable water catchment (Merry *pers. comm.* 1998). Application of herbicides to control hymenachne within catchments used to collect drinking water could cause considerable public concern. A similar problem is currently being experienced with the chemical control of the water weed, *Cabomba caroliniana*, which has infested drinking water reservoirs near Brisbane.

Dense hymenachne can block the foot valves of pumps and has prevented irrigators from obtaining water from Lion Creek, near Rockhampton (J. Barrie *pers. comm.* 1999). Similar scenarios are expected to develop elsewhere.

5.2.3 Beef

On Queensland's tropical and sub-tropical native pastures, live weight gain of beef cattle usually declines significantly in the dry season when protein becomes scarce (the so-called "protein drought"). With the assistance of the Queensland Department of Primary Industries, graziers have been experimenting with "ponded pastures" for the past 60 years as a means of establishing a source of high-protein, dry season fodder (Pittaway *et al*. 1996). Ponded pasture is a permanent pasture system that can utilise either native or introduced species of grasses. Both natural and artificial wetlands can be used for ponded pastures. Artificial wetlands are created on relatively flat land when overland water flow is trapped by the construction of earth banks. These pondage areas are then planted, usually with introduced grasses such as para grass in shallow areas (less than 60cm deep) and hymenachne or aleman grass in deeper water (up to 1.2 m deep). In the dry season, when the water has dried off, the ponded pasture is ready to be fed to stock.

Hymenachne has particular advantages as a ponded pasture species. The principal benefit is it's ability to grow in water up to 1.2 m deep, which effectively extends the use of ponded pastures to inland areas of Queensland with poor dry season rainfall and high evapotranspiration. Hymenachne has appealing agronomic characteristics, including high nitrogen values (Howard-Williams and Junk 1977), high protein content (13.9% dry matter) (Dirven 1965), an ability to remain palatable well into the dry season (Bogdan 1977) and high forage production (up to 18t dry matter per hectare per annum) (Rony Teys 1978). Established pastures maintain productivity largely through litter decomposition and N mineralisation (Weier *et al.* 1995). In Surinam, crude protein content was found to be high, 15.8% in the whole plant and 22.6% in the leaves, with crude digestibilities of 66 - 80% (Bogdan 1977).

Ponded pastures, including hymenachne pastures, can provide several advantages to graziers. They can help stabilise fluctuations in productivity which occur because of seasonal variation in forage availability and nutritive value, i.e. ponded pastures can be used in the dry season to buffer the supply of other feed (mainly native pasture). Consequently, returns from beef production can be stabilised and generally increased, and product quality maintained throughout the year. In times of drought, ponded pastures enable pastoralists to maintain viable herd sizes and, at the same time, help to prevent land degradation due to overstocking (Smith and Olive 1991).

Jamieson and Bourne (1996) assessed the profitability of ponded pastures in Queensland's grazing lands. The analysis concluded that ponded pastures could yield satisfactory returns and increase whole property profits under the right circumstances. The slope of the land and other geographic features that reduce the cost of earthworks were considered the most critical aspects of profitability. Ponded pastures are likely to be profitable on slopes of less than 0.5% with deeper ponds (1 m) providing better returns than shallower ponds (deeper ponds provide green feed longer into the dry season). Ponded pastures established on slopes greater than 0.5% are unlikely to yield satisfactory profits due to high costs associated with bank construction and maintenance. Most suitable and profitable areas have less than 0.2% slope and suitable topography is very limited in northern Australia (Miles and Wildin 1996).

Ponded pastures can be used to reclaim scalded land. In a survey of pastoralists in the Northern Territory, Stockwell *et al*. (1996) documented the successful use of shallow ponding on scalded areas to reduce soil sodicity and allow establishment and regeneration of native and introduced pasture species. Ponded pastures can also be used to trap sediment and nutrients that would otherwise be transported further down a catchment (P. Pittaway, *pers. comm*. 1999).

Wildin and Chapman (1987) estimate that a 100 ha pond grazed at a stocking rate of 1 beast/ha, with each beast gaining 180kg liveweight per annum, can potentially provide an income of approximately $15,000 above the return expected from undeveloped land. Of course, this figure can only be achieved if sufficient water is available and many land holders would not have access to sufficient flat land and catchment area to yield such returns. Development costs and water pumping costs will vary in different areas as will maintenance costs.

The likelihood of large parts of catchments or sub-catchments being ponded is not high, due to the limited number of suitable sites available given practical and economic considerations. Seldom more than 5 - 10% of a property that can be ponded. Of 170 central Queensland landholders surveyed by Cummins (1991), only 20 owned ponded areas exceeding 100 ha.

The native wetland grass, *Hymenachne acutigluma*, has significant value as a ponded pasture grass in tropical areas and was the main species grazed by water buffalo in the tropical floodplains of the Northern Territory. It exists in north Queensland but plantings have not persisted south of Mackay (Wildin *et al*. 1996b). Calder (1981) investigated the distribution, fertiliser response, growth pattern, potential use and productivity of native hymenachne in the Northern Territory. Native hymenachne has considerable potential as a tropical ponded pasture but this potential appears to have been largely ignored in northern Australia, in favour of robust exotics that are more readily available.

The impact of hymenachne on the Central Queensland grazing industry is generally believed to be positive. However, the plant is considered far less valuable in the 'wet tropics' region, where alternative dry season fodder is often in good supply.

5.2.4 Fisheries

In coastal Central Queensland, the construction of earth banks across intertidal creeks to capture fresh runoff water for ponded pastures and to prevent salt water intrusion is reported to have caused fish kills (Harris 1991). Harris (1991) commented that ponded pastures constructed on marine plains are "the perfect fish trap" since fish swim over the banks during exceptionally high tides but cannot escape when the water recedes. Construction of pondage banks has alienated large areas of marine plains from the marine environment and caused destruction of mangroves. In the Broadsound area of Central Queensland some 6,500 ha of marine plains have been impounded (Cummins 1991). Marine plains play an important role as nursery areas and refuges for the juvenile stages of many estuarine species and as a nutrient source for the adjacent estuarine area (Garrett 1991, Clarkson 1995). Changes to natural sediment depositional processes caused by bank construction could affect sea grass populations and dependent fauna such as prawns, turtle and dugong (Byron 1991). Doohan (1991) stated that ponded pastures have been constructed without any assessment of impacts on the marine environment and inshore fisheries – a departure from the processes adopted for other major developments. He suggests a correlation between increases in ponded pastures and a decline in barramundi numbers and outlines a range of potential impacts including interference with nutrient flows, fish kills, reduction of freshwater flows, impact on spawning and releases of sediment (in the event of bank failure).

Barramundi spawn near the mouths of estuaries and juveniles utilise coastal swamps, supralittoral salt pans, marine pans, marine plains and flood plains as nursery areas (Coates and Unwin 1991). These authors state that "Ponded pastures which prevent access to and from these areas will have an adverse effect on barramundi populations." The average annual commercial catch of barramundi from the Queensland east coast is approximately 158 tonnes and is valued at some $2.4M. In the decade to 1998, the commercial catch of barramundi from the coastline between Cape Cleveland and Alva Beach was 91 tonnes and is conservatively valued at $1.37M (M. Lightowler and M. Cappo, *pers. comm*. 1999). This stretch of coastline more or less encompasses Bowling Green Bay, an area where hymenachne appears poised to invade.

Concern over the destruction of fishery habitat and an ensuing heated debate between commercial fisherman and graziers resulted in a workshop entitled "Probing Ponded Pastures" being held in July 1991. As a result of discussions at the workshop, the Minister for Environment and Heritage placed a moratorium on further bank construction on coastal marine plains (Miles 1996).

The spread of monospecific stands of hymenachne in natural wetlands, including the banks of creeks and rivers, will modify the habitats of native invertebrates and other aquatic microfauna, thereby impacting on dependent populations of native fish. Modification could include decreased water flow (caused by large masses of hymenachne), stagnation, increased levels of organic matter and increased levels of soil nitrogen. Die-back of hymenachne in dry periods might have an adverse impact on water quality due to the high biological oxygen demand of rotting organic matter in shallow water (V. Veitch *pers. comm*. 1999). Depending on the nature of these modifications, some species of aquatic life may be favoured and others eliminated or reduced in numbers. Commercially valuable species of native fish, such as barramundi, have evolved to utilise specific habitats. If these habitats are changed dramatically, there is the chance that these fish will be lost or reduced in abundance.

The introduction of hymenachne has facilitated an expansion of ponded pasture systems established along rivers and streams. In some areas, this is expected to reduce total run-off volumes and either diminish or stop natural flows. Many estuarine fish and trawl species (prawns, bugs etc.) breed in response to natural flood events and substantial disruption to natural run-off patterns will probably reduce their recruitment success. Interference in nutrient exchange processes could also affect prawn production in adjacent areas. For the coastline between Bowen and Tully, the average annual value of four commercial prawn species (king, tiger, banana and endeavour prawns), caught between 1988 – 1995, was $14.5M (Ludescher 1997).

5.2.5 Environment and eco-tourism

Hymenachne forms extensive, pure stands within seasonal, fresh-water wetlands in its native range (tropical America). As such, it has the potential to invade and possibly dominate habitats with similar climatic and edaphic attributes in northern Australia. Humphries *et al*. 1991 and Csurhes and Edwards 1998 have nominated hymenachne as a 'potential environmental weed' in its early stages of spread. Conservation authorities fear that hymenachne might invade native wetlands at the expense of native marsh plants. Of particular concern is the plant's potential to damage extensive wetlands within the World Heritage listed Kakadu National Park. In 1992 Kakadu attracted approximately 220,000 visitors (Hill and Press 1993). The area generates some $30M per annum and is responsible for 6% of employment in the Northern Territory (Knapman *et al*.

1991). Although Queensland's wetland Parks attract fewer visits, their potential tourism value is substantial and needs to be protected.

Hymenachne grows free from its coevolved range of pests and diseases. Therefore, it may have a competitive advantage over certain native marsh species, such as the native grasses *Pseudoraphis spinescens* Vick., *Paspalum distichum* L. and *Leersia hexandra* Sw., which are naturally dominant in seasonal freshwater marshes of northern and central Queensland. Sainty and Jacobs (1994) suggest that hymenachne might occupy a niche sometimes filled by water lilies (*Nymphaea* spp.) and pink lily or native lotus (*Nelumbo nucifera* Gaertn.).

Macrophyte invasion of lowland stream banks and the resulting sedimentation together can have a pronounced effect on aquatic ecosystem function (Bunn *et al*. 1997, Bunn *et al*. 1998). In addition to the direct loss of aquatic habitat, high benthic respiration from accumulated organic matter results in limited oxygen penetration into fine bed sediments, and few benthic organisms can survive these conditions. Much of this unconsumed plant biomass remains in the stream bed. If removal of dense macrophyte growth is attempted, mobilisation of trapped organic material and sediment could cause problems for downstream marine ecosystems (Bunn *et al*. 1998).

If native plant communities are lost or modified, dependent native wildlife, including invertebrates, fish and birds, could also become less abundant or disappear from affected areas. Water birds often depend upon specific vegetation types and structures as a source of food and for suitable nesting opportunities. Bayliss and Yeomans (1990) found that during the dry season, the abundance of magpie geese (*Anseranas semipalmata* Latham) in the Northern Territory is greatest in wetlands dominated by the native sedges (*Eleocharis* spp). During the wet season, magpie geese abundance was greatest in areas containing a broad range of native plants, including *Oryza* spp., *Eleocharis* spp., *Ischaemum* spp. and native hymenachne. The geese depend on these plants for food and secure roost sites. Similar results were obtained by Wilson (1997). Wilson (1997) commented that all freshwater wetlands in her study site on the central Queensland coast are privately owned and all property owners are actively planting introduced ponded pastures, including hymenachne, into these natural wetlands. Although magpie geese appear to utilise small stands of hymenachne, it is not known what impact the development of extensive, pure stands of hymenachne will have on bird populations.

Creation of artificial wetlands and modification of existing wetlands results in the loss of natural vegetation communities that existed prior to bank construction. Development of ponded pastures has allowed an expansion of cattle grazing into sites that would otherwise enjoy *de facto* conservation status (e.g., coastal *Melaleuca* wetlands). Media releases on the benefits of ponded pastures have proclaimed that these new grasses could "transform totally unproductive coastal ti-tree swamps into a commercial cattle breeding and fattening showplace" (Gladstone Observer 24 January 1990). The benefits of ponded pastures have generally been promoted with little, if any, thought given to their impacts on the environment or eco-tourism.

As pointed out by Csurhes (unpubl.), the importation and promotion of invasive grasses seems to be in direct contradiction to the aims of several international agreements to protect biodiveristy, viz.: International Convention on Biological Diversity, Convention Concerning the Protection of the World Cultural and Natural Heritage, Convention on Wetlands of International Importance (Ramsar), Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment, Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment. In particular, Article 8 (in-situ conservation) of the International Convention on Biological Diversity (ratified by the Australian Government on 18 June 1993), states that "Each contracting party shall, as far as possible and as appropriate: (h) prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species."

National parks at risk of invasion include Bowling Green Bay, Edmund Kennedy (some 2500 ha of freshwater wetlands), Lakefield and Eubenangee. Bowling Green Bay National Park site has been listed under the 'Ramsar' convention as an internationally significant habitat for water birds.

Case study – Lakefield National Park

Lakefield National Park is situated in southern Cape York Peninsula and is Queensland's second largest National Park (*c.* 5,300 km^2). It was gazetted in 1979 to conserve, amongst other natural features, a large number of lakes and lagoons developed on the flood outflow of the lower reaches of the Kennedy and Normanby Rivers and their tributaries. Ponded pastures have already been investigated on a small scale within the park's catchment and at least one major development was being considered in 1991. As yet, the Park is free of hymenachne. However, considering the close proximity of ponded pasture development, the ease with which hymenachne can spread from vegetative material dislodged during floods, and the climatic similarity between this area and the plant's native habitats, invasion of the park's wetlands seems inevitable. The park's wetlands are at serious risk of degradation (Clarkson 1991).

5.2.6 Human health

The construction of ponded pastures provides ideal breeding habitat for mosquitoes (Mottram 1991). A study of mosquito larval habitats in Mexico found that areas in which hymenachne was the dominant plant supported medium and high densities of mosquito larva (Rejmankova *et al.* 1992). Substantial increases in mosquito abundance could increase the prevalence of mosquito-born diseases such as encephalitis and Ross River viruses.

5.2.7 Other

Several accounts show that hymenachne can form floating mats and "grass islands" which interfere with shipping (cause delay, damage propeller shafts, cooling systems and rudders) in rivers of South America (Bews 1929, National Science Research Council of Guyana 1973). Following flooding in north Queensland, Edwards (1997) observed large mats of hymenachne blocking a causeway. Similarly, large floating "islands" of hymenachne (*c*. 50 – 60 m in diamater) have been observed in the Fitzroy River near Rockhampton (J. Barrie *pers. comm.* 1999). Dense mats of floating vegetation are known to cause structural damage to small bridges during floods.

Poorly planned construction of ponded pastures can result in rising water table levels and salinity (Chapman and Thorburn 1991). If a pond is incorrectly located or sealed, water can leak downward to the ground water table. If there is some sub-surface restriction preventing ground waters from moving away from the ponded area, water tables can rise and salinity may result. Salinisation within the pond system itself may occur if the pond is located downstream of saline seeps or due to evaporative concentration of salts within the pond over a prolonged dry period. However, ponded pastures pose little salinity risk if the system is designed and constructed with forethought. Soil tests and analysis of landscape features can avoid problems outlined above.

Thick growth of hymenachne can block access to river banks and has impeded inspection of water meters by Department of Natural Resources and Mines (water resources) staff working in boats along the Fitzroy River (J. Barrie *pers. comm.* 1999).

Hymenachne is being promoted and planted to remove nutrients from polluted waste water. Although a wide range of native and introduced plants can be used in this way, hymenachne is considered to be one of the most useful since excess biomass can be harvested at regular intervals and fed to cattle (P. Pittaway, *pers. comm*. 1999).

5.2.8 Net benefit or cost to the State

To estimate the economic benefits of hymenachne to the State cattle industry, data is required on the total area that could be planted with hymenachne and the dollar value that each hectare could produce per annum. At present, these data do not exist. Although Wildin and Chapman (1987) estimated that ponded pasture can potentially provide an income of $150/ha/annum, the net value of hymenachne (above that of alternative species such as para grass or native ponded pasture species) is not known.
The net cost of hymenachne control is equally difficult to estimate but will depend primarily on three factors:

(1) the extent of infestations (i.e., the total area of land over which control is attempted)
(2) the control method used and its associated cost per hectare
(3) the degree of difficulty associated with getting conventional spraying equipment into infestations (i.e., site access).

P. van Haaren (*pers. comm.* 1998) estimates that control costs are likely to be in the order of $652 - $688 per hectare. This estimate is based on research results utilising the herbicide Arsenal® (imazapyr) at 2 kg active ingredient per hectare (with 100% kill). This equals 8 litres of product per hectare (a 20 litre drum of Arsenal cost $1,630 in November 1998).
The density of the infestation will affect the volume of water applied with the herbicide but not the total cost. Infestations less than a year old (seedling growth) will require less water than taller, older infestations. However, the rate of

herbicide applied (a.i. per hectare) in both cases will be the same (P. van Haaren, *pers. comm.* 1998).

A range of potential costs resulting from spraying unwanted areas of hymenachne is presented (Table 2). However, it is not possible to predict the total area that will eventually be colonised by hymenachne or the total area over which control will be attempted. As such, the net benefit (or cost) to the State is impossible to determine.

Table 2. Range of possible control costs for Statewide herbicide treatment of hymenachne (initial control costs that do not include follow-up control).

	Total area of State where chemical control is attempted (ha)				
Cost/ha	1,000	5,000	10,000	50,000	100,000
$450	$450,000	$2.25M	$4.5M	$22.5M	$45M
$650*	$650,000	$3.25M	$6.5M	$32.5M	$65M
$850	$850,000	$4.25M	$8.5M	$42.5M	$85M

*considered to be the minimum herbicide cost to control one hectare of dense hymenachne.

5.3 Potential impact of other ponded pasture species

Other non-indigenous pasture species currently being used in ponded wetlands include aleman grass and para grass. The deleterious impacts of para grass are well known since this plant has been in Queensland since 1884 (Wildin *et al*. 1996a). However, aleman grass is a recent introduction (approved for release at the same time as hymenachne) with significant invasive potential. Of concern is this plant's ability to invade deeper water than hymenachne and perhaps destroy communities of submerged or floating native plants.

Wildin (1985) and Wildin *et al*. (1996b) have suggested that several other tropical non-indigenous grasses, including *Brachiaria radicans* Napper, *Echinochloa haploclada* (Stapf) Stapf, *Echinochloa spectabilis, Echinochloa stagnina* (Retz) Beauv., *Entolasia imbricata* Stapf., *Eriochloa meyeriana* (Nees) Pilget, *Eriochloa punctata* (L.) Desv. Ex Hamilt. *Hymenachne donacifolia, Hymenachne pseudo-interrupta* C.Muell., *Leersia denudata* Launert, *Panicum elephantipes* Nees and *Vossia cuspidata* (Roxb.) Griff., as well as legume species, should be introduced and evaluated for use as new ponded pasture species. Some of these species, such as *Echinochloa stagnina*, have documented weed potential and should not be planted in Australia before a thorough evaluation of their potential benefits and environmental impacts has been completed. *Echinochloa pyramidalis* (antelope grass) is currently being evaluated in Queensland but has not been released (Leighton *et al.* 1996). Some 200,000 different genetic lines of potential pasture species are stored in 'genetic resource centres' within Australia and, unlike new plant imports, their release is not currently subject to quarantine scrutiny.
It is worth mentioning that the history of importing "improved" pasture plants into northern Australia is poor. Of 463 non-native pasture plants introduced between 1947 and 1985, only 4 species (less than 1%) have been useful without causing weed problems (Lonsdale 1994).

6.0 Biology and Ecology

6.1 Habitat

Persistence and abundance of hymenachne is influenced by a number of factors including climatic and edaphic factors. Generally, the plant prefers tropical, low-lying freshwater wetlands and flood plains. It grows most prolifically in wetlands that are subject to high nutrient and sediment influx from upstream agricultural land, but can persist in less disturbed areas. Survival is influenced by soil type, soil moisture content (especially during the dry-season), duration and depth of flooding. Within its native range, hymenachne occurs as a natural component of permanent (shallow) tropical wetlands and seasonally flooded low-lying grassy plains. A recent study by Pinder and Ross (1998) listed hymenachne within four plant formations: marsh ponds, waterlogged basins, tall grasslands and forest edges in the Brazilian Pantanal (lat. 19°57' S, long. 56°25' W). These four habitats are all inundated to varying depths during the wet (flood) season. Hymenachne is most abundant in marsh ponds, a habitat characterised by the constant presence of water (water depth range from 0 - 40 cm during the dry-season and 40 - 80 cm during the wet-season). Waterlogged basins are characterised by waterlogged (but not submerged) soil in the dry season and 40 - 50 cm water in the wet season. Within the Pantanal, the plant is less abundant, and occasionally absent, in grassland and forest edges which are dry for most of the year but inundated during the wet season. In the Venezuelan savannas, hymenachne is co-dominant with *Leersia hexandra*, in seasonally-flooded areas where the water table occurs at a depth of 30 - 60 cm below the soil surface (Tamayo 1981). Species other than hymenachne dominate in areas where the water table is either shallower or deeper during the dry season. As such, hymenachne seems to prefer seasonally flooded land in areas where its roots have access to wet or damp soil during the dry season. The plant does not thrive in well-drained sites that dry out completely during the dry season. In fact, Medina and Motta (1990) considered hymenachne to be the least drought tolerant of several grass species from seasonally flooded savannas in south-west Venezuela.

Hymenachne can become established on the margins of permanent deep water, provided the area close to permanent deep water is subject to a fluctuating water level (seasonal flooding). In this situation, the plant's floating stems reach out into deep water. The plant can survive in permanently wet areas (provided these areas are very shallow during the dry season) but does not persist when rooted in water that is deep (i.e., more than 1.2 m) throughout the year. In the Florida Everglades, hymenachne has naturalised within habitats characterised by standing water for at least nine months of the year (Kalmbacher *et al.* 1998). Similarly, Tejos (1980) reported that hymenachne can withstand a maximum flooding level of 121.5 cm and 297 days of flooding. In north Queensland, hymenachne has been observed growing in water 3 - 4 m deep. Both hymenachne and para grass are unable to tolerate saline soils and generally fail to persist in areas that are subject to occasional tidal inundation (G. Blackman, *pers. comm*. 1999).

In central and northern Queensland, other than in ponded pastures, hymenachne is growing in water storage facilities, irrigation channels, roadside ditches, natural lagoons and cane paddocks. A particularly dense infestation exists in the Haughton balancing storage where water levels fluctuate dramatically as irrigation water is pumped in and out of the facility. All of the areas where hymenachne has been found experience seasonal fluctuations in water levels and all are characterised by waterlogged or damp soils during the dry season. Some of the most vigorous stands of hymenachne exist in lowland areas where nutrients and sediments have been deposited from upstream sugar cane fields. To some degree these are an indicator of poor land management practices.

Many of Queensland's tropical and sub-tropical lowland waterways are already degraded by the introduced pasture grass (*B. mutica*) and accumulated sediment from cropland erosion (Bunn *et al*. 1998). Decreased shading of streams, caused by clearing of natural riparian vegetation, tends to trigger prolific growth of aquatic and semiaquatic macrophytes (Brookes 1994, Gore 1994, Wade 1994). The combined effect of clearing riparian vegetation and increased sediment loads appears to have facilitated invasion by hymenachne along the banks of many lowland tropical and sub-tropical streams. L. Childs (Livingstone Shire Council, *pers. comm.* 1999) comments that hymenachne appears to initially invade streams that contain heavy loads of nutrients and sediment. In situations where tall, natural vegetation provides shade over the banks of lowland streams, growth of hymenachne is expected to be less prolific.

There is very little information available on the influence of soil type on hymenachne survival and abundance. Failure of hymenachne to establish in research trials in Florida have been attributed to soil type (Kalmbacher *et al*. 1998). However, the authors did not fully investigate the influence of soil type on hymenachne and it is possible that failure was due to an unfavourable soil moisture regime rather than type *per se*. In tropical America, the plant is generally considered to be an indicator of waterlogged, swampy areas (Gonzalez-Jimenez and Escobar 1977).

6.2 Adaptations to wetland environment

Hymenachne is well suited for survival in seasonally flooded freshwater wetlands. When subject to inundation, hymenachne is capable of rapid stem elongation, stem dry matter production and nodal adventitious root production (Weier *et al.* 1995). Rapid elongation of the stem maintains the leaves above the water for the exchange of gases and allows emergent leaves to function at full photosynthetic capacity (Kibbler 1997). In Venezeula, Tejos (1978a) found that hymenachne growth increased with increasing depth of flooding and that greatest forage production was achieved under flooded, compared with dry season, conditions. Biomass production ranged from 5,911 - 18,162 t/ha/yr during the flood period and from 5,553 - 7,836 t/ha/yr during the dry season, depending on the interval between cuts. Tejos (1978b) found that hymenachne grew most rapidly when the water level increased slowly and that growth was minimal when water level declined.

An association appears to exist between nitrogen-fixing bacteria and the roots of hymenachne (Weier *et al*. 1995). This association enhances the plant's ability to persist on low fertility soils (Miles and Wildin 1996). Nitrogen fixation rates are believed to be higher in newly established stands compared to mature stands, with litter decomposition and mineralisation being the major avenues for maintaining productivity in mature stands (Weier *et al*. 1995).

6.3 Reproduction and dispersal

Following promotion by the Queensland Department of Primary Industries in the late 1980's, runners of hymenachne have been transported and planted widely in ponded pasture systems on grazing land throughout coastal and sub-coastal north and central Queensland. Examples are known of runners being sent from far north Queensland to the Broome area in Western Australia (Clarkson 1995). Once runners are established and the plant matures, seed production is prolific.

According to Lukacs (1996), hymenachne can be readily established in ponded pastures by planting pieces of mature grass (a piece with two nodes is sufficient), either by hand or machine. Alternatively, larger pieces can simply be cast from boats. Floating pieces in shallow water soon put down roots and grow on contact with the soil (Lyons 1989).

Fragmentation of plant stolons can be caused by physical disturbance including damage caused by flowing water. Fragments can be carried considerable distances downstream by floodwaters or when pondage banks fail. Hence, seasonal flooding, usually associated with summer rainfall in Queensland, is allowing the plant to spread.

Hymenachne can spread rapidly from seed, readily germinating and producing a dense seedling cover wherever conditions are suitable (Anning and Kernot 1991). In Florida, germination is variable, ranging from 0 - 86%, and factors affecting seed fertility are not clearly understood (Hill 1996). Research staff from the Queensland Department of Natural Resources and Mines have noted that when seeds of hymenachne were placed in germination trays and watered regularly by conventional over-head sprinklers, germination rates were very low. However, when seeds were subjected to waterlogged conditions for 48 hours, high germination rates were observed (J. Vitelli, *pers. comm*. 1999). Hence, it appears that waterlogging is required to trigger germination. In north Queensland, Lyons (1996) reported that hymenachne seed is 98% viable, which is much higher than para grass (up to 16% viable seed). Lyons (1996) commented that he had established hymenachne in a pond by simply throwing seeds into the water, after which seedlings emerged as the pond dried out. While seed of hymenachne is commercially available, most plantings have utilised vegetative material. There is little information available on seed longevity. Informal research undertaken by the Tropical Weeds Research Centre in north Queensland found that after 16 months storage at room temperature (20 - 30^{o}C) in the laboratory, only 10% of seeds remained viable (J. Vitelli, *pers. comm*. 1999).

Experience has shown that hymenachne, and other exotic ponded pasture species, cannot be adequately contained within artificial pondage areas and escape is inevitable. A major problem is bank failure caused by either poor contruction techniques, dispersible soil types and the erosive action of storm or flood water runoff. For example, the heavy wet season in 1990/91 saw breaching of many new pondage banks (Kernot 1996). Similarly, Smith (1996) commented that he had experienced failure of banks due to the dispersible nature of local soils. In addition, there is anecdotal evidence that birds can transport and deposit the plant's seeds.

Once hymenachne has established in irrigation water storage facilities, further spread occurs via irrigation water contaminated with seeds and runners.

Case study

After attending a field day in May 1987, a grazier from the Charters Towers area, planted a few runners of hymenachne in a small dam on his property. By 1993, there was a dense population of hymenachne covering several hectares. It was estimated that 99% of the population originated from seeds (Lyons 1996).

6.4 Phenology

In Queensland, flowering usually occurs from around mid-April to May. Seed is set from late autumn to early spring each year (Wildin and Chapman 1987, Wildin 1991). However, plants have also been observed flowering in September and there is anecdotal evidence that the plant can flower and set seed over a longer length of time in unusually wet years, compared to drier years (J. Vitelli, *pers. comm*. 1999). In Florida, flowering and seed production occurs in autumn, which coincides with the end of the wet season (Hill 1996). An extended flowering period, from September to March, has been observed in the West Indies (Adams 1972).

7.0 Efficacy of Current Control Methods

7.1 Chemical control

Preliminary herbicide screening trials undertaken by the Queensland Department of Natural Resources and Mines indicate that at least three herbicides, Arsenal 250®, Fusilade® and Round-up Biactive®, can reduce hymenanche biomass by more than 90%, when applied as high volume foliar sprays (Table 3). However, substantial regrowth from stolons was observed 87 days after herbicide application on plants treated with either Fusilade® or Round-up Biactive®. The herbicide showing most promise is imazapyr (Arsenal 250®), which is not yet registered for use on hymenachne.

There could be major limitations to the future use of Arsenal. Since it is a broad-spectrum herbicide, it will kill most plants that it comes in contact with. Its application in natural wetlands could damage or kill native wetland plants and could facilitate re-invasion of treated sites by hymenachne of other opportunistic plants. In addition, Cox (1996) has outlined concerns regarding the safety, persistence and mobility of imazapyr (sold as Arsenal).

Table 3. Preliminary results from herbicide screening trials in north Queensland (source: P. van Haaren, Queensland Department of Natural Resources and Mines, unpublished).

Herbicide	Product (a.i./L)	Biomass reduction (%)	
		Trial 1 (87 dat*)	Trial 2 (87 dat*)
Arsenal 250®	250	96.6	98.3
Fusilade®	212	97.3**	96.7
Velpar L®	250	8.3**	81.3**
Round-up Biactive®	360	94.0**	66.7**
Verdict®	130	na	60**
Asulox®	400	na	13.3**
Balance®	750	na	1.7**
Sencor®	480	14.3**	na
Control	nil	0	0

* days after treatment, ** healthy foliage regrowth observed, na – data not collected

Repeated application of Round-up Biactive®, applied as a high volume foliar spray, has been used with some success to control a dense infestation of hymenachne in the Haughton Balancing Storage. Initial herbicide treatment caused above-ground stem and leaf material to turn brown and fall close to ground level. Once dry, this material was burnt. Prolific regrowth and seedlings were then sprayed again (J. Ready, pers. comm. 1999). The site is still subject to re-invasion and some regrowth of live stolons.

If initial herbicide application, followed by burning, is completed prior to the plant setting seeds, regeneration from seedlings is poor. However, if material is burnt after the plant has set seeds, there may be as many as 500 seedlings/m^2 produced (J. Vitelli*, pers. comm.* 1999).

7.2 Mechanical/physical control

It might be possible to control the plant in some artificial water storage facilities by lowering the water level (drying the plant) or maintaining high water levels (to "drown" the plant), since hymenachne does not tolerate excessively dry or wet sites. However, this has never been tried before and there has not been any research on mechanical/physical control of hymenachne in Australia. The plant is difficult to remove by hand since it snaps off readily at each node. Mechanical removal of hymenachne in drains, using heavy earth-moving machinery, has been undertaken in north Queensland with some success. Solar sheeting (plastic sheeting) can kill the plant, but is only suitable for relatively small areas.

7.3 Biological control

Since hymenachne is closely related to native hymenachne, classic biocontrol is highly unlikely due to host-specificity problems. There do not appear to be any significant pests of hymenachne in Australia.

7.4 Land management practices

Shading by tall vegetation offers a long-term, cost-effective and ecologically sound means of controlling aquatic weeds, compared with chemical and mechanical methods (Wade 1994, Smith *et al*. 1995). The latter are often less effective due to re-invasion by the same species or replacement by other weed species (Harris 1988, Hobbs and Mooney 1993). Recently, shading has been investigated as a potential form of control for para grass. In a study conducted in a coastal tropical stream in north Queensland, biomass of para grass growing under 90% shade was only 22% of that in open areas (Bunn *et al*. 1998). Shading produced by the retention and regeneration of tall riparian vegetation may help control hymenachne where it poses a problem along the banks of creeks and lagoons. However, it is unlikely to be a practical option in freshwater marshlands that are naturally free from shrubs and trees.

Heavy grazing by cattle can reduce the total above-ground biomass of hymenachne, but is unlikely to kill the plant. Natural stands of hymenachne growing in South America are noted for their ability to withstand heavy grazing. Stevenson (1948) found that under overstocking on the 'pegasse' pastures of British Guiana, hymenachne was frequently the only grass survivor and that it occurred in pure colonies intermixed with the sedge *Cyperus articulatus*. Drought, perhaps combined with intense grazing pressure, seems to have eliminated hymenachne from ponded pastures in some of the inland areas of north Queensland. In fact, in the Local Government areas of Croydon and Etheridge, the plant is considered to be a total failure (P. Horrocks pers, comm. 1998).

8.0 Management and Control Practices

8.1 Legislative status in Queensland

Hymenachne is not a declared plant in Queensland, as defined by the Queensland *Rural Lands Protection Act* 1985. However, Cairns City Council has listed it as a noxious plant under local law and several other Local Governments in north Queensland are considering similar legislative measures.

8.2 Legislative status in other States

Currently, hymenachne is not a declared plant in any other State of Australia. However, if the plant continues to be used as ponded pasture it will undoubtedly naturalise in natural wetlands and demand for control will develop. Smith (1995) commented that hymenachne has the potential to form dense and extensive monospecific stands in the seasonally flooded areas of the Northern Territory. Hymenachne has recently been planted at the Coastal Plains Research Station (Smith 1995) and is currently being planted to the west of Kakadu National Park (P. Barrow, Kakadu Park Ranger, *pers. comm.* 1998).

8.3 Demand for declaration and control in Queensland

Due to the plant's increasing impact on sugar cane, irrigation facilities and natural wetlands in north Queensland, demand for enforced control is increasing. Strong demands for restrictions and declaration have been received from canegrowers, Local Governments throughout the 'wet tropics', conservation interests and commercial fishermen. Grazier groups have expressed concern at the "bad publicity" directed at hymenachne in north Queensland media in recent years and are quick to defend the plant's value as a dry-season source of cattle fodder in coastal Central Queensland.

8.4 Containment and eradication strategies in Queensland

Eradication of hymenachne from Queensland is highly unlikely due to the plant's resilience, extensive distribution, a lack of registered herbicides (other than glyphosate) and reluctance by graziers to destroy a valuable pasture plant. Even if highly effective herbicides became available, it is doubtful that all infestations of the plant could be found. In addition, treated areas are expected to be quickly re-infested from seeds and stem fragments washed in from neighbouring areas.

Containment of spread may be possible but would require substantial resources and a co-ordinated containment program utilising enforced control by all land holders. It may be desirable to attempt containment within the 'wet tropics' zone were the plant is causing the greatest problems, especially within major irrigation and cane growing regions. Enforced control within catchments containing natural wetlands of high conservation value is also desirable. Enforced control on grazing land elsewhere in the State would be opposed by most graziers.

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