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Abstract

This report summarises work conducted by the QDPI, in partnership with the South Burdekin Water Board (SBWB) and the Burdekin Shire Council (BSC) between 2001 and 2003. The broad aim of the research was to assess the potential of native fish as biocontrol agents for noxious weeds, as part of an integrated program for managing water quality in the Burdekin Irrigation Area. A series of trials were conducted at, or using water derived from, the Sandy Creek Diversion near Groper Creek (lower Burdekin delta).

Trials demonstrated that aquatic weeds play a positive role in trapping transient nutrients, until such time that weed growth becomes self-shading and weed dieback occurs, which releases stored nutrients and adversely affects water quality. Transient nutrient levels (av. TN<0.5mg/L; av. TP<0.1mg/L) found in the irrigation channel during the course of this research were substantially lower than expected, especially considering the intensive agriculture and sewage effluent discharge upstream from the study site. This confirms the need to consider the *control* of weeds rather than complete weed extermination when formulating management plans. However, even when low nutrient levels are available, there is competitive exploitation of habitat variables in the irrigation area leading to succession and eventual domination by certain weed species. During these trials, we have seen filamentous algae, phytoplankton, hyacinth and curled pondweed each hold competitive advantage at certain points. However without intervention, floating weeds, especially hyacinth, ultimately predominate in the Burdekin delta due to their fast propagation rate and their ability to out-shade submerged plants.

We have highlighted the complexity of interactions in these highly disturbed ecosystems in that even if the more prevalent noxious weeds are contained, other weed species will exploit the vacant niche. This complexity places stringent requirements on the type of native fish that can be used as biocontrol agents. Of the seven fish species identified with herbivorous trophic niches, most target plankton or algae and do not have the physical capacity to directly eat the larger macrophytes of the delta. We do find however that following mechanical weed harvesting, inoculative releases of fish can slow the rate of hyacinth recolonisation. This occurs by mechanisms in addition to direct weed consumption, such as disturbing growth surfaces by grazing on attached biofilms. Predation by birds and water rats presents another impediment to the efficacy of large-scale releases of fish. However, alternative uses of fish in water quality management in the Burdekin irrigation area are discussed.

Introduction

Concerns over high nutrient loads in waterways include social, economic and environmental issues that range from human health impacts to ecological damage on offshore reefs. North Queensland's Burdekin region, particularly, has come under increased scrutiny recently for its suspected contribution to nutrient enrichment of the adjacent Great Barrier Reef (GBR) lagoon (Productivity Commission 2003, Science Panel 2003). While there remains conjecture over the extent to which particular human activities contribute to nutrient enrichment of the GBR lagoon (Furnas 2002), Haynes & Michalek-Wagner (2000) suggest diffuse sources such as agricultural run-off from grazing and cropping industries, as a whole, are the most significant contributor.

The intensive agriculture in the Burdekin delta, particularly sugarcane farming, is sustained through the use of water from the Burdekin River and the delta groundwater reservoir, delivered through a complex series of irrigation channels and lagoons. Post irrigation water is returned to the groundwater table via recharge pits or discharged into downstream estuaries. Water managers in the region wish to maintain the quality of water within and exiting the irrigation system. A major aspect of this is the control of excessive aquatic weed growth that occurs within irrigation channels and lagoons.

Aquatic weeds can impede the free flow of water and contribute to increased seepage and water table rises in the adjoining areas. Aquatic weeds may also lead to water logging, indirectly create saline or alkaline conditions in the soil, and promote the growth of many other land weeds (Lancar & Krate 2002). Seasonal high-flow events in the Burdekin (such as floods, water releases from the upstream reservoir and periods of peak irrigation) increase suspended solids and turbidity in waterways, which favour the growth of floating weeds over phytoplankton and submerged macrophytes (Tait & Perna 2001, Furnas 2002). These weeds can impede farming operations (eg, by clogging pumps) and reduce water quality for native aquatic animals by depleting dissolved oxygen supplies. Tait & Perna (2001) suggest that fish diversity and abundance has dropped dramatically in Burdekin waterways in recent decades.

Despite the problems associated with aquatic weed growth, they do serve a valuable role in trapping and storing transient nutrients. While weeds remain actively growing, they assimilate nitrogen and phosphorous from the water, accumulating nutrients that would otherwise impact on downstream estuaries. Aquatic plants also provide a surface area for attached microbial growth, which further aids nutrient processing (Redding *et al.* 1997). However, when weed growth becomes prolific, self-shading causes dieback and subsequent release of nutrients. Flood events also disperse weed masses downstream and overland where their decay liberates the stored nutrients. Preventing all weed growth therefore would result in reduced nutrient removal and storage, while allowing weeds to grow unchecked results in decay and nutrient release. The challenge facing the Burdekin community is how to manage weed growth and improve water quality without negating the benefits of aquatic weed nutrient removal. Weed *control* rather than complete weed extermination is the most desirable strategy.

Throughout the world, various measures are used to control aquatic weeds (see Lancar & Krake 2002 for a review). They consist of three basic approaches: chemical control, biological control, and mechanical methods. Chemical control has been trialed in the Burdekin using herbicides, but this approach is costly, potentially hazardous to the environment, and returns bound-up nutrients to the waterway as weeds die and decompose. Likewise, biological control through the release of water hyacinth weevils has shown some success in the Burdekin but the destruction of the weeds creates high organic loading of the waterway, releasing nutrients and depleting dissolved oxygen. Currently in the Burdekin, mechanical harvesting of waterweeds is the only management option employed on a large scale. This too is costly, given the large number of channels and the frequency with which they need to be harvested. Furthermore, the many tonnes of harvested weed must be carried off-site to prevent it rotting and releasing nutrients back into the system.

Aquatic weeds can be a valuable food source for omnivorous fish and this has been used as a mechanism for weed control in other parts of the world (Van der Zweerde 1990). For biological control using fish to form part of an integrated approach to aquatic weed and water quality management in the Burdekin, we would need new knowledge of the efficacy of different native fish species. Ideally, these fish could then be harvested – thus physically removing nutrients from the system - and sold for profit. But an immediate and more realistic goal is to reduce the frequency of mechanical weed harvesting and to restore the irrigation channel habitat to a more natural state. A further spin-off is that these fish could assist with vector control (mosquitoes and midges).

This report summarises work conducted by the QDPI, in partnership with the South Burdekin Water Board (SBWB) and the Burdekin Shire Council (BSC). The broad aim of the research was to assess the potential of native fish as biocontrol agents for noxious weeds, as part of an integrated program for managing water quality in the Burdekin Irrigation Area. Specific aims were as follows:

- Identify all potential weed-grazing fish species native to the Burdekin catchment.
- Identify potential of their large-scale culture (artificial breeding) and secure sufficient animals to conduct on-ground experiments.
- Assess their ability to restrict aquatic weed growth.
- Determine the influence of finfish on nutrient dynamics

Materials and Methods

Study site

Sandy Creek Diversion, a cane farm channel near the Groper Creek community, was the selected principal study site as it is an end-point for irrigation water within the southern system and should be an indicator of nutrient levels discharged into the estuary. A series of experiments were undertaken within the study site or using water sourced from this irrigation channel in a pilot-scale experimental system constructed at Groper Creek.

Sandy Creek Diversion has a typical aquatic weed profile within the delta's irrigation area (Photo 1). Our census of aquatic weeds within this channel was conducted during June 2001 and abundances were quantified according to high, medium or low densities corresponding to surface area coverage (Table 1). This information identified trophic niches that should be targeted by potential biocontrol agents.

Table 1. Major aquatic weeds found within the Sandy Ck Diversion study site.

Common Name	Scientific Name	Type	Density
Water hyacinth	*Eichhornia crassipes*	Floating	High
Salvinia	*Salvinia molesta*	Floating	High
Water lettuce	*Pistia stratiotes*	Floating	Low
Azolla	*Azolla pinnata*	Floating	Low
Duckweed	*Spirodela punctata*	Floating	Low
Para grass	*Brachiaria mutica*	Emergent	Medium
Olive Hymenachne	*Hymenachne amplexicaulis*	Emergent	Low
Cumbungi	*Typha sp.*	Emergent	Medium
Cabomba	*Cabomba caroliniana*	Submerged	Medium
Hydrilla	*Hydrilla verticillata*	Submerged	Low
Curled pondweed	*Potomogeton crispus*	Submerged	Low
Filamentous algae	*Rhizoclonium spp*	Submerged	Low

Identification of potential biocontrol agents

An inventory of freshwater fish species historically recorded from freshwater lagoons in the Burdekin area (Macleay 1883), or with distributions that fall within the region (Merrick & Schmida 1984, Allen *et al*. 2002) was reviewed. Of over 42 species (including two exotics), only seven native species were identified with herbivorous trophic niches (Table 2).

Table 2. Herbivorous freshwater fish of the lower Burdekin delta.

Common Name	Scientific Name	Trophic Niche
Banded grunter	*Amniataba perchoides*	Omnivore
Snub-nosed gar	*Arrhamphus sclerolepis*	Algavore/planktivore
Bully mullet	*Mugil cephalus*	Detritivore/algavore
Bony bream	*Nematalosa erebi*	Algavore
Scat	*Selenotoca multifasciata*	Detritivore/macroinvertivore
Milkfish	*Chanos chanos*	Planktivore
Pipefish	*Parasygnathus sp.*	Planktivore

After comparing fish trophic preferences with prevalence of weed types recorded in the channel it was clear that planktivorous fish species would be of little value (the dominating fibrous macrophytes had inhibited phytoplankton production). Additional criteria for selecting biocontrol agents included tolerance to channel water quality, large-scale culture potential and (for the current trials) availability. Based on these criteria, mullet (*Mugil cephalus*), banded grunter (*Amniataba perchoides*), and scat (*Selenotoca multifasciata*) were selected as the most appropriate candidates.

Trial A – Groper Creek pilot trial

In June 2001, an experimental system was constructed at Groper Ck, consisting of two 20-ton plastic header (storage) tanks feeding four smaller (10-ton) treatment tanks (Photo 2). Each of the treatment tanks represented an artificial irrigation lagoon and had its own regulated supply tap, with water sourced from the Sandy Ck Diversion. Aeration was not provided to the tanks.

Each of the four treatment tanks was equipped with eight sheets of artificial substrate (Photo 3). Substrate assists in simulating actual lagoon conditions by providing a surface for the development of bacterial biofilm (periphyton), which aids in nutrient processing (ultimately release of gaseous nitrogen to the atmosphere) as well as a growth surface for algal communities that provide food for foraging fish (Azim *et al*, 2001). The substrate was a commercially available product called Aquamat^{tm}. Following the addition of substrate, water was added and flow rates standardised at a rate of 700l/day.

After a one-month period to establish a biotic community on the substrate, fish were introduced into two of the tanks. The two experimental treatments were therefore *plus* and *minus* fish. Fish stocking details are described in Table 3.

Table 3. Details of fish used in experimental system

Species	Length (mm)	Weight (g)	Stocking Density
Mullet	138	36.7	15/tank
Scat	105	18	4/tank
Banded grunter	120	88	4/tank

Nutrient sampling of incoming and discharged water occurred every 4 days according to standard methods (APHA, 1989) for dissolved and total nitrogen and phosphorous analysis. Samples were stored at –18°C until collected and analysed (monthly).

By September 2001 it was apparent that general productivity in the tanks was poor, due to the very low levels of influent nutrient from the irrigation canal. At this stage it was decided that to test the true potential of the system, a more nutrient rich water source was required and the water collection site was changed to a nearby lagoon downstream of the local sewage treatment facility. Water was also sourced from a nearby tap that accessed groundwater under the Groper Creek site.

At the completion of the trial in mid December 2001, algae in the treatment tanks was collected and weighed. Sub-samples of algae and aquamat were then analysed to calculate their overall nutrient content within the treatment. All nutrient analyses were carried out on a Lachat QC8000 flow injection analyser according to standard methods (QuikChem methods, 1996). We thank Rodger Wilkie for volunteering to sample the system from July to November. Unfortunately the sampling program could not be strictly adhered to during the last month of the experiment (November) due to a shortage of sample bottles on site. Nutrient data for the majority of November contains dissolved nutrient results only.

Nutrient assimilated by fish in the system was calculated according to published formulae (Lupatsch *et al*, 1998) and essentially assumes fish are composed of 15 percent protein. With these data, we calculated a budget of total nutrients entering, retained and leaving the simulated lagoons.

Trial B - Inoculative mullet release

A limitation of the pilot trial (Trial A above) was that no fibrous macrophytes became established in the ‘simulated’ lagoons (the experimental system was dominated by naturally occurring filamentous algae – see Results). As fibrous macrophytes – especially hyacinth and salvinia – dominate Burdekin waterways, we needed to assess the efficacy of native fish to control these plants in ‘real’ irrigation channels.

This trial assessed the consequence of adding mullet to the channel habitat after mechanical harvesting of weeds. Road culverts at each end of a 300m long (x 6.5m wide) stretch of Sandy Ck Diversion provided suitable barriers, once screened, to enclose the study site. An artificial barrier was placed mid-way along this stretch and also screened, providing a 'Mullet' section (downstream) and a 'Control' section (upstream).

In June 2002, the channel was mechanically harvested using a backhoe operated weed rake. Approximately 700 mullet were stocked into the 'Fish' section. The 700 included 500 hatchery-reared fish (mean weight: 40g) and approximately 200 locally wild-caught fish (size range:15-500g). Stocking density was therefore approximately 0.7fish/m^2.

Water quality (Total and Dissolved Inorganic Nitrogen, Total Phosphorous, Temperature, Dissolved Oxygen, and pH) was monitored at start and end points of the trial site (i.e. water entering the Control stretch; at the junction of the Control and Mullet stretch; and leaving the Mullet stretch). The influence of mullet on the channel habitat was assessed by mapping weed regrowth monthly in the Mullet stretch and the Control stretch using tape measures and quadrat sampling.

Trial C – Fish pen trial

Stocking different combinations of species and/or size classes of biocontrol agents may enhance the capacity of native fish to restrict weed growth by fostering exploitation of a wide range of niches within the channel. This trial aimed to assess whether the size of the stocked mullet influenced their ability to target dominant weed types. Further, we assessed banded grunter and scats as potential biocontrol agents.

This trial was conducted in mesh fish pens (1.5m diameter) within the Sandy Ck. Diversion study site (Photo 4). Following mechanical weed harvesting in May 2003, eight fish pens were installed (fastened to the substrate to prevent movement) and dominant weeds from the channel were stocked into each pen as follows:

Water hyacith: 1.2kg
Salvinia: 1.0kg
Cabomba: 1.0kg

Fish were stocked into the pens by random allocation two weeks after the weeds were introduced. The mullet and scats were from stocks held at the Bribie Island Aquaculture Research Centre, and the banded grunters were wild-caught. Repeated attempts, however, to acclimatise scats to full freshwater failed in fish over 400g. Scats smaller than 400g remained alive for at least two weeks but showed signs of distress (limited movement; inability to remain fully upright). Only juvenile scats less than 20g showed no signs of distress from prolonged exposure to freshwater. Hence, scats were excluded from the trial. The treatments used in the trial therefore were small mullet, large mullet, and banded grunter at holding densities appropriate for the fish pen size (Table 4). After two months, the pens were harvested to assess weed biomass and fish growth. Water quality monitoring continued during the trial period.

Table 4. Treatment, fish density and starting weight in fish pen trial.

Fish Pen No.	Treatment	Mean Size (g)
2 and 6	Small mullet (x35)	36 and 31
5 and 7	Large mullet (x10)	392 and 359
3 and 8	Banded grunter (x22)	47 and 42
1 and 4	Control (no fish)	n/a

Trial D – Recharge pit efficiency

An additional component of the study was a preliminary investigation into whether stocking detritivorous fish assisted in maintaining recharge efficiency in groundwater recharge pits. The concept was for mullet to graze on aquatic weeds on the substrate of the pit and keep particles locally suspended, thereby aiding water penetration. 'Vas' Recharge Pit, located at Home Hill within the southern irrigation system was selected for this trial. This pit, when activated, has a surface area of approximately 700m^2.

The pit basin was scraped using a backhoe in June 2002 to remove the compacted surface layer, and recharging commenced. Subsequently, a total of 1000 juvenile hatchery-reared mullet (mean weight: 25g) were released into the pit.

Typically, groundwater recharging continues until effectiveness (rate of infiltration) is reduced due to clogging of the substrate by aquatic vegetation – specifically benthic algae. There were some limitations to this preliminary trial. First, flow rates could not be measured. Second, there was no replication (only one pit was used). Therefore, the role of mullet was assessed qualitatively by comparing the recharge period with previous years, and by assessing the substrate cover compared with another local pit at the conclusion of recharging.

Results

Trial A – Groper Ck pilot trial

Fish Data: Mullet increased their weight by 12% over 20 weeks in the tanks. This represented a level of nitrogen assimilation of 110 mgN/fish, or 1.65 g/tank (Table 5) assuming protein content of 15% per fish (Lupatsch *et al*, 1998). The banded grunter did not grow in the tanks and in fact, showed a slight loss in weight. This may be due to the spawning of some of the larger females while in the tanks. Their spawning resulted in the presence of many post-larval fish in the tanks. The scats died after several weeks in the tanks so they were not factored into final nutrient budgets in this trial (although their decomposition may have added some nitrogen).

Table 5. Fish growth and nutrient assimilation.

Fish	Avg. initial weight (g)	Avg. initial length (mm)	Avg. final weight (g)	Avg. final length (mm)	Assimilated nitrogen (g/tank)
Mullet	36.7	138	41.3	160	1.65
Banded grunter	87.7	120.5	81.6	121.1	0

Aquatic Weed Data: There was significantly more macro algae colonisation in the *minus* fish treatment than the *plus* fish treatment (Photo 5). Without fish, filamentous algae (*Rhyzoclonium* sp.) covered the surface of the water and the bottom of the tanks but was not prevalent on the artificial substrate. The *plus* fish treatment also showed some growth of this aquatic weed, however this growth was confined to the surfaces of the artificial substrate and was not found on the surface or on the bottom of the tanks. No hyacinth or salvinia growth occurred in the tanks.

To calculate nutrients retained in the treatments, the aquatic weed on the artificial substrate and throughout the water column was weighed and analysed for nitrogen content. In the *minus* fish treatments, results indicate that 102.8 g of nitrogen was bound up in the weed representing 59.5% of the total nitrogen entering the system. Of this, only 23.4 g or 13.5% was in weed confined to the substrate. In the *plus* fish treatment, which contained less algae, 71.7 g of nitrogen was retained in weed on the substrate representing 41% of the total incoming nitrogen.

Nutrient Discharge Data: Total phosphorous in discharge was on average 25% of the incoming value for the *minus* fish treatment (discharge value of 0.14 mgP/L relative to incoming amount of 0.55 mgP/L) and 31% for the *plus* fish treatment (0.17 mgP/L relative to 0.55 mg/L, respectively) (Figure 1). Mean phosphorous discharge from the two treatments was not significantly different from each other (P>0.05).

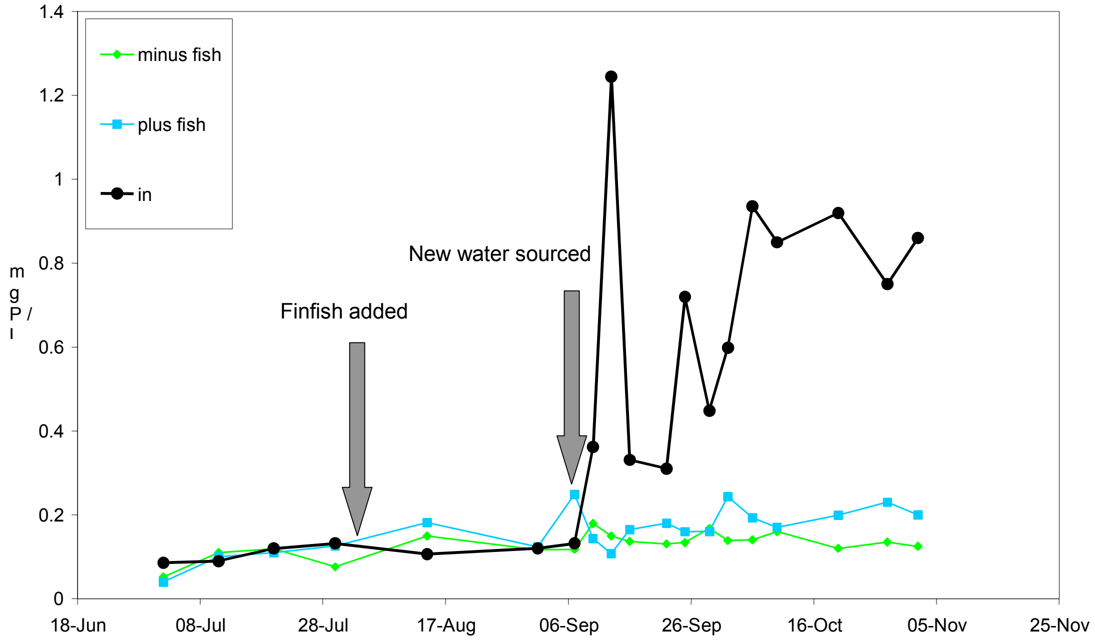

Figure 1. Total phosphorous profile for the *plus* and *minus* fish treatments over the experimental period.

Total nitrogen discharge from the *minus* fish treatment was 50% of the total incoming value (mean discharge value of 0.72 mgN/L relative to mean intake value of 1.46 mg/L) and discharge from the *plus* fish treatment was 54% of total incoming nitrogen (mean discharge value of 0.78 mgN/L). Average discharge nitrogen between treatments was not significantly different from each other (P>0.05). However, during the last month of total nitrogen sampling, discharge from the *plus* fish system was consistently higher than the *minus* fish system (Figure 2), and this difference was significant (P<0.05).

Mean dissolved inorganic nitrogen (DIN), i.e. ammonia, nitrite and nitrate, discharged from the *minus* and *plus* treatments was 0.019 mgN/L and 0.014 mgN/L respectively, relative to mean intake value of 0.48 mg/L (Figure 3). These discharge levels from both treatments were low and highlight the efficiency of algae for removing DIN from the water column. The majority of nitrogen released therefore, was in a form other than ammonia or nitrate (i.e. particulates, phytoplankton). Low Total Ammonia Nitrogen levels are generally recognised as limiting for the processes of nitrification, however, nitrification rates within treatments were not measured.

From visual observations it was evident that the *minus* fish system was mostly free of suspended solids suggesting that the majority of released nitrogen was in the form of dissolved organic compounds. Nitrogen discharged from the *plus* fish system was mostly phytoplankton and resuspended particulate material (Photo 5).

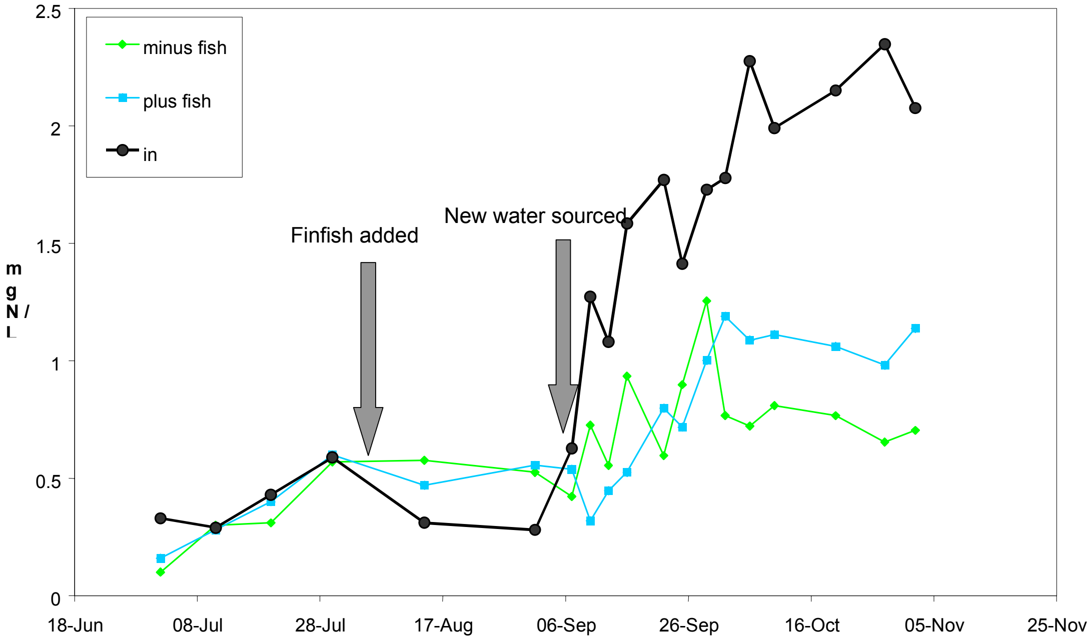

Figure 2. Total nitrogen profiles for the *plus* and *minus* fish treatments over the experimental period.

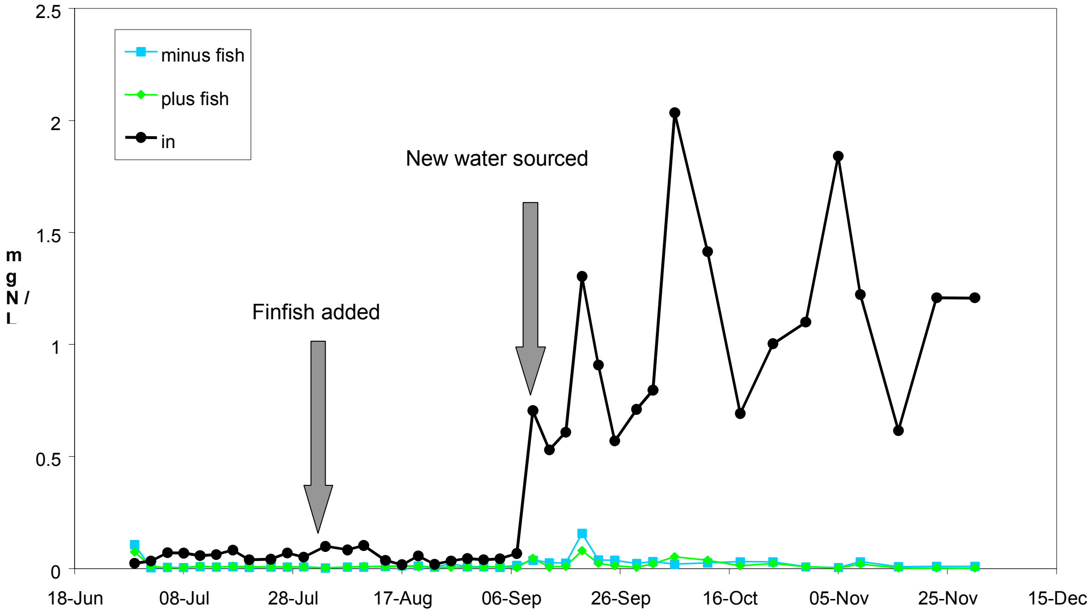

Figure 3. Dissolved inorganic nitrogen (DIN) profiles for the *plus* and *minus* fish treatments over the experimental period.

Overall Nutrient Balance: Total nutrient profiles for the *minus* and *plus* fish treatments showed that both systems removed appreciable amounts of phosphorous and nitrogen from the incoming water. However, nutrient pathways were different between treatments as evident in the overall nitrogen budget for the trial (Table 5).

Table 5. Calculated Nitrogen budget for the trial. ($n = 2$)

Treatment	Incoming (g)	Retained (g)	Discharged (g)	System Total (g) Retained + Discharged
Minus Fish	Total N: 172.9	Algae in water column*: 79.4	Total N: 85.4	Total N: 188.2
	DIN: 57.1	Algae on substrate: 23.4	DIN: 2.4	
	Other N: 115.8		Other N: 83.0	
Plus Fish	Total N: 172.9	Algae in water column*: 0	Total N: 93.3	Total N: 166.65
	DIN: 57.1	Algae on substrate: 71.7	DIN: 1.7	
	Other N: 115.8	Fish: 1.65	Other N: 91.6	

* Includes all algae (floating and benthic) not attached to artificial substrate

There is some minor discrepancy in the derived nitrogen budget (eg, Total N Retained + Discharged should equal Total N Incoming in a balanced nutrient budget). These can be attributed to the inherent errors in sub-sampling or unrecorded processes (nitrification denitrification). In addition, the lack of complete water samples from the final month of the trial meant that Total Nitrogen values were calculated using averaged data up until November 5th while Retained Nitrogen values were determined at the conclusion of the trial in mid December.

The possibility that the missing nitrogen in the *plus* fish budget was lost through nitrification/denitrification is low due to the low ammonia/ nitrate encountered in the treatment. The efficiency of the algae at out-competing nitrifying bacteria for ammonia has been reported in other studies (Krom *et al*, 1995). Additionally, the presence of algae on substrate surfaces inhibits denitrification by increasing the localised oxygen concentration within the substrate biofilm (Bitton, 1994). A more likely explanation for the unaccounted nitrogen is the dense phytoplankton bloom witnessed in *plus* fish treatment during the last month of the trial. This would have elevated the average discharge value if these samples were available for inclusion in the analyses. Nevertheless, the calculated budget balanced within 10%, indicating the accuracy of the analyses.

Trial B – Inoculative mullet release

Floating weeds (a mix of water hyacinth and salvinia) dominated the study site prior to mechanical weed harvesting (Photo 1) by covering greater than 95% of the study area. Of these floating weeds, randomised quadrat sampling showed that hyacinth constituted 78% with salvinia constituting 21%, based on surface area. Small quantities of azolla and duckweed were interspersed. Mechanical harvesting wasn't able to remove all of the floating weeds so when the trial commenced, remnant floating weeds made up 2.9% and 5.7% coverage of the 'Mullet' and Control stretches, respectively.

Area of weed coverage was mapped monthly after fish were stocked. After 14 weeks, aquatic weeds had revegetated 97.4% and 98.4% of the Mullet and Control sites, respectively, based on surface area (Fig 4). Floating weed coverage was readily assessed as it accumulated at the down-wind ends of each section. Floating weed cover was 8.3% and 16.0% of total surface area in the Mullet and Control stretches, respectively. This difference between sites was proportionate to the remnant floating weed coverage recorded at the start of the trial, so therefore may not be necessarily attributable to the presence of mullet. However, species composition of floating weeds varied significantly ($P<0.01$) between Mullet and Control stretches after 14 weeks, as measured by randomised quadrat sampling. As a standardised comparison per m^2 of floating weeds, Hyacinth constituted 8% and 42.9% in the Mullet and Control stretches, respectively. Conversely, salvinia coverage was significantly greater per m^2 of floating weeds in the Mullet stretch (Photo 6). Whether this shift in species composition was truly attributed to the mullet alone could not be determined without further replication, and this was a primary consideration in Trial C.

A submerged benthic weed became the new dominant plant species at the study site (Photo 7). After 14 weeks, the Curled Pondweed, *Potomogeton crispus*, covered virtually the entire study site that wasn't under shade by the floating weeds. It occurred in both the Mullet (87% area coverage) and Control (79% area coverage) stretches. The lower densities in the control stretch corresponded to the greater coverage of floating weeds at this site (Fig 4). Only minor patches of cabomba and hydrilla were present within the benthic growth.

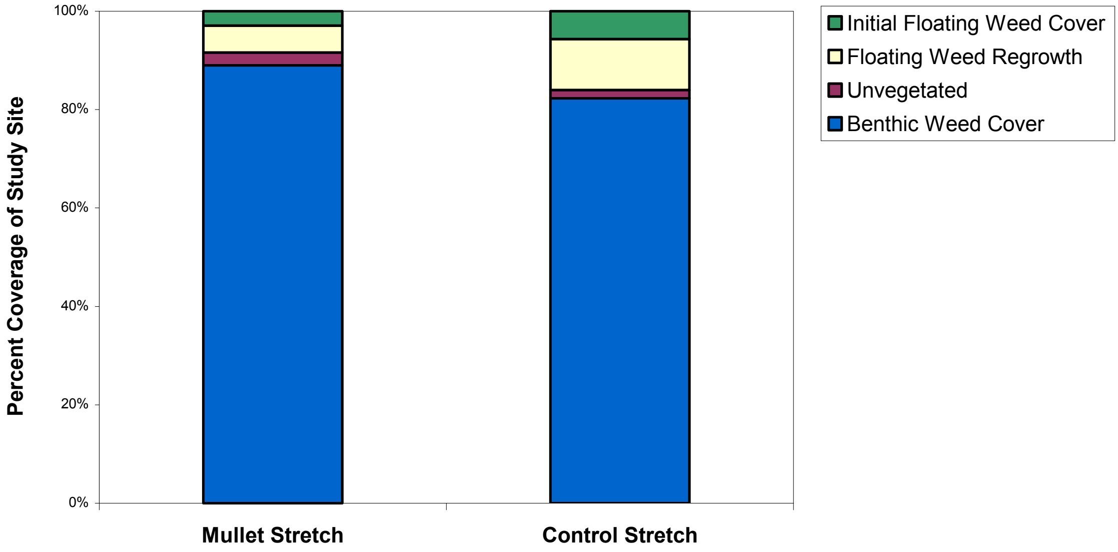

Figure 4. Composition of aquatic vegetation types in the Sandy Ck. Diversion study area, after 14 weeks of the trial.

While SBWB officers report that *P. crispus* has been a part of the aquatic plant assemblage in the Burdekin region for some time, it is usually seen in low densities and is out-competed by the hyacith (B. Lowis & C. Papale, pers. Comm.). Curled pondweed poses greater problems to routine farm operations than floating weeds as it restricts water flow through the channels. In addition, leaf fragments regularly clogged screens at the trial site causing management problems with the experiment. Consequently, the current trial was terminated. A significant observation during the period was the apparently heavy predation on stocked fish by birds.

SBWB officers collected water samples during the trial period. Analyses demonstrated that only low levels of nitrogen and phosphorous were present in the water at the study site (av. Total N=0.44mg/L; av. Total P=0.11mg/L). However, the trend was for increasing Nitrogen levels at downstream sampling points (both for dissolved inorganic species, i.e. ammonia, nitrite & nitrate; and organic nitrogen) (Fig 5). Both inorganic and organic forms of phosphorous were similar between sampling points (Fig 6).

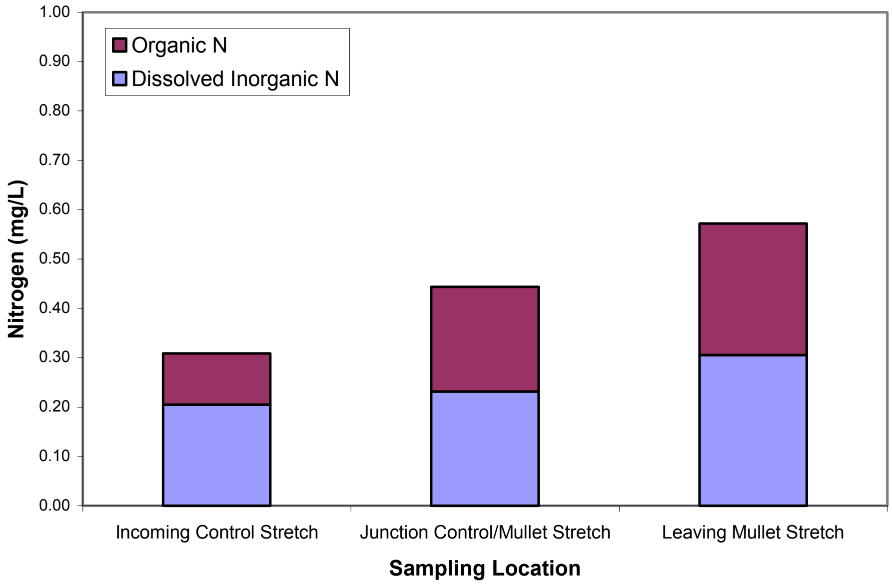

Figure 5. Total Nitrogen at start and end points of the Control and Mullet study sites, averaged over the 14 weeks of Trial B.

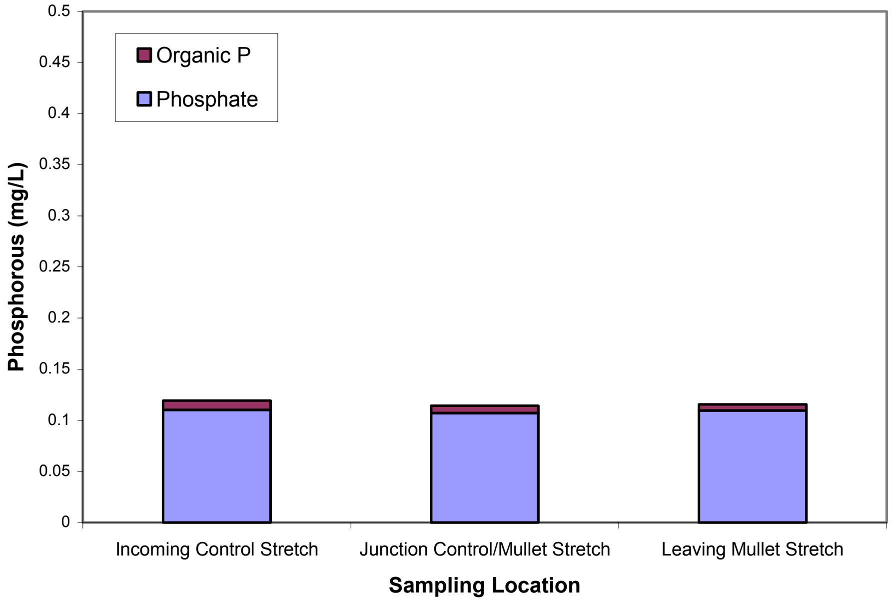

Figure 6. Total Phosphorous at start and end point of the Control and Mullet study sites, averaged over the 14 weeks of Trial B.

Prior to initial weed harvesting of the study site, dissolved oxygen (DO) was less than 1mg/L. During the trial, there was a trend for increasing DO at downstream sampling points, corresponding to irrigation water leaving the heavily weeded channel area upstream from the study site. Mean DO levels entering the Control stretch, at the junction of the Control and Mullet stretch, and leaving the Mullet stretch, were 3.0mg/L, 3.3 mg/L, and 4.4mg/L, respectively. Mean pH was maintained between 6.9 and 7.8 during the trial but showed no specific trend.

Trial C – Fish pen trial

Eight weeks after fish were stocked, the fish pens were harvested to assess weed and fish growth. Average recorded regrowth of weeds is shown in Table 6.

Table 6. Regrowth of dominant weeds in fish pens after eight weeks.

Weed Type	Initial Weight (kg)	Av. Final Weight (kg) Control Pens*	Av. Final Weight (kg) Small Mullet Pens*	Av. Final Weight (kg) Large Mullet Pens*	Av. Final Weight (kg) Banded Grunter Pens*
Hyacinth	1.2	8.885	11.362	16.979	9.246
Salvinia	1.0	4.340	3.381	3.229	4.316
Cabomba	1.0	0.505	0.855	0.227	0.390

*n=2

Hyacinth regrowth dominated over salvinia and cabomba in all pens, however the Control Pens (no fish) actually recorded the least amount of regrowth. It was difficult to draw any conclusions from these results, especially considering the following: during harvest it was observed that pens containing fish each had been perforated just below water level. Holes were clearly gnawed through the mesh netting, presumedly by water rats. Consequently, fish had either been predated upon or had escaped. This caused a significant loss of data from this trial, and as such, no validation of results from Trial B could be made. This does, however, highlight that predation from both birds and water rats could be a significant impediment to using fish in irrigation channels.

Water quality monitoring continued during the trial period. Again, only relatively low levels of transient nitrogen and phosphorous were evident in the channel (Figure 7).

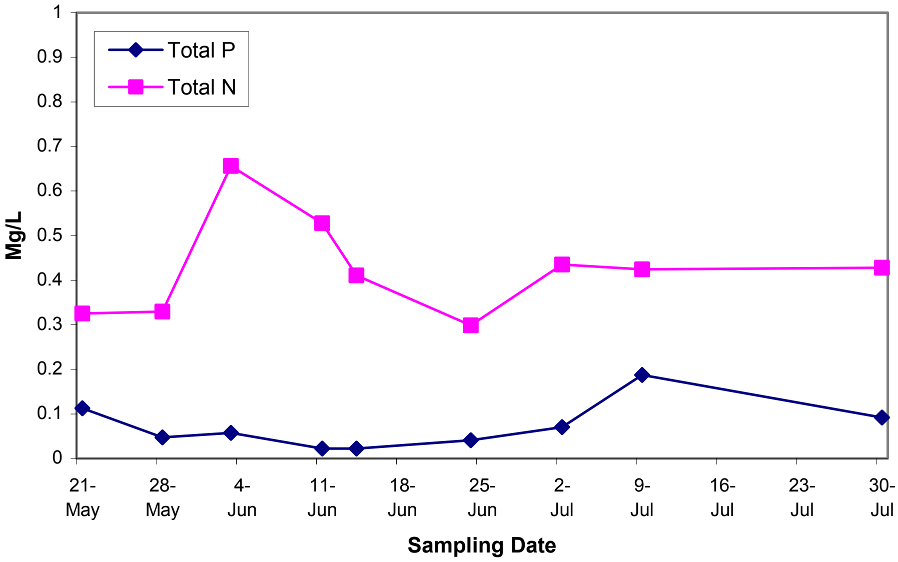

Figure 7. Total Nitrogen and Phosphorous levels recorded at Sandy Ck. Diversion during Trial C.

Trial D – Recharge pit efficiency

Groundwater recharging was maintained for four months before efficiency was reduced due to clogging of the substrate. When the pit was drained, benthic samples were analysed. The cause of the clogging was not aquatic weed as previously encountered; rather it was a fine silt layer approximately 5mm in thickness. In addition, the SBWB report that the recharge capacity of this pit was extended by at least a month over previous years. Predation of fish by birds however, was observed towards the conclusion of the trial as water levels dropped.

Whether the limited pit algae growth and extended recharge period was due to the presence of mullet or to other habitat variables resulting from the uncharacteristically dry seasons preceding the trial cannot be validated at this time. However, a smaller unstocked recharge pit in the region also showed a predominant build up of silt, rather than benthic algae on its substrate.

Discussion

Burdekin irrigation channels and lagoons provide ideal habitats for the prolific growth of water weeds: shallow, warm water temperature, abundant sunshine, consistent water level, nutrients from local and upstream sources, lack of predators. Competitive exploitation of these habitat variables leads to succession and eventual domination by certain species, as seen in both our tank and channel trials. During these trials, we have seen filamentous algae, phytoplankton, hyacinth and curled pondweed each hold competitive advantage at certain points. However, floating weeds, especially hyacinth, ultimately predominate in the Burdekin delta due to their fast propagation rate and their ability to out-shade submerged plants. The regular inundation of turbid irrigation water from the upstream reservoir, which inhibits photosynthesis by submerged vegetation and phytoplankton, also provides a competitive advantage for floating weeds.

Biocontrol of these weeds may be a useful tool in the Burdekin where other methods have failed or are impractical, provided there are built-in mechanisms to protect non-target species and the ecosystem from unintended consequences. Biocontrol agents generally require extensive contained testing to ensure their target specificity (Thomas & Willis 1998). Fish as biocontrol agents, in the current situation, may therefore be a better choice than insects or pathogens since they do not pose a risk to terrestrial vegetation and crops. When releasing fish into the aquatic ecosystem of the Burdekin, we need to consider potential interactions with the downstream marine reaches that remain connected to the irrigation area – especially in times of flood. Using fish native to the delta as biocontrol agents is therefore precautionary. Large-scale inoculative releases of native fish would be designed to augment the existing or former populations – provided that appropriate native species can be identified.

The current study has shown that the choices of native fish are, unfortunately, rather limited. Of the seven fish identified with herbivorous trophic niches, most target plankton or algae and do not have the physical capacity to eat the larger macrophytes of the delta. The pilot trial (Trial A) demonstrated that the absence of larger weeds could precipitate a phytoplankton bloom, so there may be a role for larger planktivorous species, such as milkfish, gar and bony bream, to sequester nutrients if floating macrophytes could be controlled.

The only species that offered promise therefore, were mullet, banded grunter and scats. Banded grunter and mullet have been successfully bred in captivity at the Bribie Island Aquaculture Research Centre, and breeding protocols have been documented for scats by Barry *et al.* (1993), so supplying these stock for routine release is at least possible. However, the failure of larger scats to be acclimatised to freshwater limits their value as freshwater biocontrol agents. While wild scats reportedly enter freshwaters (Merrick & Schmida 1984) and juveniles are common as freshwater aquarium species (Grant 1999), other authors too have reported difficulties in maintaining larger scats in full freshwater for prolonged periods (Mohapatra & Venkateswarlu 1992, Lee *et al.* 1993).

Banded grunters too, appear to offer limited value as agents for biocontrol according to results of Trial A, which demonstrated they lost weight during the trial period. Unfortunately, due to predation by water rats in the fish pens (Trial C), we cannot conclude that they do not target the dominant vegetation in the Burdekin irrigation area. However, banded grunters are generalist feeders (Allen *et al.* 2002), and our observations in tanks at BIARC indicate that they exhibit preference for softer, low-fibre plants.

Mullet are efficient detritivores and although macroalgal tissue can be found in their gut, they are not recognised as active consumers of macrophytes due to their lack of biting mouthparts (Brusle 1981). Our pilot study (Trial A) also demonstrated that while mullet had a profound affect on filamentous algae growth, they converted very little into tissue growth, suggesting that they reduced weed growth by mechanisms in addition to direct consumption, such as disturbing growth surfaces by grazing on attached biofilms. While we never expected mullet to consume the fibrous hyacinth in the current trials, it was envisaged that large numbers of mullet might restrict the growth of this weed by physically harassing the root system as they grazed on the attached biofilms. While hyacinth regrowth was significantly less with mullet than without in Trial B, the replicated fish pen trial (Trial C) unfortunately could not confirm this due to the loss of experimental stock by predation.

The prolific growth of curled pondweed in Trial B was unusual according to SBWB officers and may be due to seasonal variables. There was an atypical lack of rainfall prior to and during the trial period, which meant that overland flows and associated water turbidity were reduced. This, combined with the mechanical removal of floating weeds at the start of the trial, meant that benthic weeds were able to flourish during the trial period. Clearly, the growth of curled pondweed could not be related to a treatment effect since it grew equally well in both stretches. Why the pondweed out-competed planktonic algae or the traditionally more prevalent cabomba, however, is not known. This highlights the complexity of interactions in these ecosystems, in that even if the more prevalent noxious weeds are contained, other weeds may exploit the vacant niche.

Our nutrient analyses show that these weeds will grow when even low levels of nutrients are available. In fact, transient nutrient levels (av. TN<0.5mg/L; av. TP<0.1mg/L) found in the irrigation channel during the course of this research were substantially lower than community expectations, especially considering the intensive agriculture and sewage effluent discharge upstream from the study site. This again confirms the positive role aquatic plants play in trapping waterborne nutrients, and the need to consider the *control* of weeds rather than complete weed extermination when formulating management plans. To this end, well managed mechanical harvesting of weeds appears to be the best option in lieu of further information, with regards to improving water quality. Again, however, the many tonnes of harvested weed must be carried off-site to prevent it rotting and releasing nutrients back into the system. This presents an ongoing cost for management agencies.

While the results of our trials demonstrated that fish native to the area have limited ability to control noxious weeds, detritivores such as mullet may have a role in conjunction with known insect biocontrol agents such as salvinia and hyacinth weevils. Alone, insect biocontrol agents have shown success in destroying floating weeds (Lancar & Krake 2002); however, the decaying plant material perpetuates the nutrient cycle in stream. Stocked mullet would feed on this detritus, reducing the organic load with positive outcomes for water quality.

There are other, albeit problematic, biocontrol approaches to consider, such as using sterilized exotic weed-eating fish such as the white amur or grass carp (*Ctenopharyngodon idella*). Grass carp should not be confused with the European carp (*Cyprinus carpio*) or its variants that are declared noxious in Queensland, and which are known to create environmental problems where they are found in Australia (Allen *et al*. 2002). Grass carp are native to certain rivers in China and Russia, and are specifically herbivorous with feeding habits quite different from the European carps (Jhingran & Pullin 1988). They are known to target many of the problematic weeds now common in the Burdekin irrigation area, and have been used successfully around the world, including India, USA, Hungary, Costa Rica, Japan and New Zealand (Thomas 1994, Clayton 1996, Refs in Lancar & Krate 2002). Established protocols to artificially induce sterility ensure that numbers released are strictly controlled to prohibit natural reproduction and undesirable impacts on the native aquatic habitat. For example, in Florida, only certified triploid (sterile) grass carp may be used, with an accurate ploidy quality control used to ensure 100% sterility prior to release (Thomas 1994). We understand, however, that introducing these fish to the Burdekin system, even with built-in safety checks, would contravene current state stocking and translocation policies. This represents a significant hurdle if this approach is to be pursued.

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References

Allen, G.R., Midgley, S.H. & Allen, M (2002) Field Guide to the Freshwater of Australia. Western Australian Museum. 394pp.

APHA (1989) Standard methods for the examination of water and wastewater. Eds: L. S. Clesceri, A.E. Greensburg, and R. Trussell. *American Public Health Association*. 17th edition.

Azim, M.E., Wahab, M.A., van Dam, A.A., Beveridge, M.C.M., Milstein, A. and Verdegem M.C.J. (2001) Optimisation of fertilisation rate for maximising periphyton production on artificial substrates and the implications for periphyton-based aquaculture . *Aquaculture Research*. **32**: 749-760.

Barry, T.P., Castanos, M.T., Paz Soccoro, M., Macahilig, C. & Fast, A.W. (1993) Spawning induction in female spotted scat (*Scatophagus argus*). *Journal of Aquaculture in the Tropics*. **8**:121-129.

Bitton, G. (1994) Fundamentals of microbiology, IN: Wastewater microbiology. Wiley-Liss, USA.

Brusle, J. (1981) Food and feeding in the grey mullet. In: Aquaculture of grey mullets. (ed. by O. H. Oren), Cambridge University Press, London.

Clayton, J.S. (1996) Aquatic weeds and their control in New Zealand lakes. *Lake and Reservoir Management* **12(4)**:477-486.

Furnas, M. (2002) Catchments and Corals Terrestrial Runoff to the Great Barrier Reef, AIMS and CRC Reef, Townsville.

Grant, E. (1999) Grant's Guide to Fishes. E.M. Grant Pty Ltd, Scarborough. p457.

Haynes, D. & Michalek-Wagner, K. (2002) Water quality in the Great Barrier Reef World Heritage Area: past perspectives, current issues and new research directions. *Marine Pollution Biology*. **41**:428-434.

Jhingran, V.G. & Pullin R.S.V. (1988) A Hatchery Manual for the Common, Chinese and Indian Major Carps. Asian Development Bank. 191 p.

Krom, M, D., Ellner, S., van Rijn, J. & Neori, A. (1995) Nitrogen and phosphorous cycling and transformation in a prototype non-polluting integrated mariculture system. Mar. Ecol. Prog. Ser. **118(1-3)**: 25-36.

Lee, C.L., Peerzada, N. & Guinea, M. (1993) Control of aquatic plants in aquaculture using Silver Scat, *Selenotoca multifasciata*. *Journal of Applied Aquaculture*. **2**:77-83.

Lupatsch, I., Kissil, G., Sklan, D. & Pfeffer, E. (1998) Energy and protein requirements for maintenance and growth in gilthead seabream. *Aquaculture Nutrition*. **4**: 165-173.

Merrick, J.R. & Schmida, G.E. (1984) Australian freshwater fishes: biology and management. Griffin Press Limited, Netley, South Australia.

Mohapatra, A. & Venkateswarlu, T. (1992) Acclimatization of *Scatophagus argus* (Linnaeus) in Freshwater. *Environment & Ecology* **10**:454.

Productivity Commission (2003) Industries, Land Use and Water Quality in the Great Barrier Reef Catchment, Research Report, Canberra. 415pp.

QuikChem Methods (1996) Operators Manual. Zellwegar Analytics Inc. Lachat Instruments Division, Milwaukee WI 53218, USA

Redding, T., Todd, S. & Midlen, A. (1997) The treatment of Aquaculture wastewaters – a botanical approach. *Journal of Environmental Management* **50**:283-299

Science Panel (GBR Reef Protection Interdepartmental Committee Science Panel) (2003) A Report on the Study of Land-Sourced Pollutants and Their Impacts on Water Quality in and Adjacent to the Great Barrier Reef. http://www.premiers.qld.gov.au/about/reefwater.pdf.

Tait, J. & Perna, C. (2001) Fish habitat management challenges on an intensively developed tropical floodplain: Burdekin River North Queensland. *RipRap 19*. Land and Water, Australia, Canberra.

Thomas, P.W. (1994) The use of grass carp in Florida: past, present and future. *Lake and Reservoir Management* **9(2)**:119

Thomas, B.A., & Willis, A.J. (1998) Biocontrol – risky but necessary? *Trends in Ecology & Evolution.* **13**:325-329.

Van der Zweerde, W. (1990) Biological control of aquatic weeds by phytophagus fish. In: Aquatic Weeds. The Ecology and Management of Nuisance Aquatic Vegetation. *Oxford University Press, Oxford*. Pp 201-221.

Photographs

Photo 1. Sandy Creek Diversion study site: before mechanical weed harvesting (top) and after (bottom)

Photo 2. Experimental tank system at Groper Creek township (Trial A)

Photo 3. Artificial substrate in experimental tanks in Trial A to provide a growth surface for bacteria and aquatic weeds.

Photo 4. Mesh fish pens used in Trial C, showing weed regrowth after eight weeks, dominated by hyacinth covering the surface. The pens were constructed with a mesh lid to prevent bird predation, however, fish were still predated upon by water rats that gnawed through the 21-ply polyethylene mesh.

Photo 5. Experimental tanks in Trial A. *Minus* fish tank (left) with prolific weed growth on the surface and bottom of tank. *Plus* fish tank (right) with weed growth confined to the substrate only. Note the presence of a phytoplankton bloom in the *Plus* fish tank.

Photo 6. Species composition of floating weeds varied between Control (top) and Mullet (bottom) stretches after 14 weeks in Trial B. Hyacinth regrowth was significantly reduced with the presence of mullet. Conversely, salvinia coverage was significantly greater per m^2 of floating weeds in the Mullet stretch. Note: SBWB officers changing screens at the culvert junction of the Control and Mullet stretches (top), and the prolific growth of benthic Curled Pondweed in the Mullet stretch beyond the culvert.

Photo 7. The benthic Curled Pondweed, *Potomogeton crispus*, became the new dominant weed species at the study site in Trial B. After 14 weeks, curled pondweed covered virtually the entire study site that wasn't under shade by the floating weeds. It occurred in both the Mullet (87% coverage) and Control (79% coverage) stretches.