# INFLUENCE OF NATIVE FISH ON WATER QUALITY AND WEED GROWTH IN CANE FARM IRRIGATION CHANNELS: A PILOT SCALE STUDY

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## Summary

A DPI-SBWB-Burdekin Council consortium, within the framework of the Lower Burdekin Initiative, assessed the influence of native fish (mullet and banded grunter) on the water quality and aquatic weed growth in the Burdekin. The trial was conducted over five months at Groper Creek (lower Burdekin delta) in simulated cane farm irrigation lagoons. Naturally occurring aquatic weeds (mostly filamentous algae, *Rhizoclonium* spp.) removed appreciable quantities of nutrients (>50%) from incoming source water. However, without fish, aquatic weed growth was prolific through the water column and on the water surface. With fish, growth of the weed was restricted to artificial substrates in the tanks, and there was no surface or bottom fouling. Reduced weed growth from the presence of fish precipitated a phytoplankton bloom and increased overall suspended solids concentrations in the water column towards the end of the trial. A caveat of this trial is that only filamentous algae appeared in the experimental system, so no data were collected regarding fibrous macrophytes. However, results based on the current data suggest that fish can prevent the deterioration in physical water quality caused by excessive weed growth in irrigation lagoons. To further improve nutrient recovery (eg. sequester nutrients currently lost to phytoplankton) we may need to consider the inclusion of a greater range of species in the system (eg. herbivorous fish and plankton consumers such as mussels).

## Introduction

Queenslands Burdekin region produces around 25% of the nation’s annual sugarcane production (Shannon & Raine, 1996). The intensive agriculture in the area is sustained through 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 lower estuaries of the Burdekin delta via channels and to the groundwater table via recharge pits.

Sugarcane is an intensively managed crop; large dosages of artificial fertiliser are applied to consistently maintain high yields. Since the 1950's the use of artificial fertiliser has increased dramatically in north Queensland leading to speculation that there may be some nutrient enrichment of the coastal environment resulting from cane farming practices. This represents a major issue facing the long-term sustainability of sugarcane agriculture in the Burdekin shire.

As well as questions of long term sustainability there are also more immediate issues facing the Burdekin sugarcane farmers. One issue is that of excessive aquatic weed growth in the irrigation channels supplying and draining farms. This weed growth is not only an impediment to day to day farm irrigation practices, but also negatively impacts on the aquatic ecosystem within these waterways.

Excess aquatic weed growth can adversely effect physical water quality causing, in particular, major dissolved oxygen (DO) fluctuations. There is clear evidence to suggest that fish diversity and abundance has dropped substantially in the Burdekin waterways in the last ten years (ACTFR, unpublished data), most likely due to the choking of waterways with aquatic weed and increased BOD and reduced dissolved oxygen levels.

Weed growth, despite ecological and industrial detractions, does perform an important function in the removal and storage of nutrient leaving farms. This can lead to a transient reduction in the quantity of nitrogen and phosphorous entering the GBR lagoon. However, when weed growth becomes severe, self-shading, senescence and algal death results in the release of stored nutrients. Hence preventing all weed growth would result in minimal nutrient removal, but, allowing unchecked weed grow results in decay and nutrient release (Erler *et al*., 2000).

The challenge facing the farming community in the Burdekin is how to control aquatic weed growth and improve water quality without negating the benefits of aquatic weed nutrient removal. Presently the only available option is mechanical harvesting of weed affected lagoons. This can be a costly exercise, given the large number of channels and the frequency with which they need to be harvested. Furthermore, the many tonnes of weed removed must be utilised to prevent it rotting and re-entering the irrigation system as nutrient. Due to these reasons mechanical harvesting alone is a poor long-term solution.

Aquatic weeds can be a valuable food source for omnivorous fish and this can be a useful mechanism for weed control (Van der Zweerde, 1990). If enough nutrients can be assimilated by the fish then significant overall nutrient removal can also result, provided the fish are harvested and removed from the system.

In Australia the role of native fish for the control of aquatic weed and nutrient assimilation is very poorly understood. There is the potential for the use of native species such as mullet (*Mugil cephalus*), striped scat (*Selenotoca multifasciata*), banded grunter (*Amniataba percoides*), milkfish (*Chanos chanos*) and others to contribute to weed control and possibly nutrient removal. With this in mind the DPI-LBWB-Burdekin Council consortium conducted a pilot scale trial to assess the influence of fish in the control of aquatic weed infestation. This report details the results from this trial and suggests some future related works.

## Broad Aims

- Investigate potential strategies for the removal of aquatic weed, and associated nutrients, from cane farming irrigation channels.

## Specific Aims

- Determine the influence of detritivorous and herbivorous fish on aquatic weed growth and survival.
- Determine the influence of detritivorous and herbivorous fish on nutrient dynamics.

## Methodology

In June 2001 an experimental system was constructed at Groper Creek, a small fishing community east of Home Hill, within the Burdekin delta (Figure 1). The system consisted of two 20 ton plastic header tanks feeding five smaller (10 ton) treatment tanks. Each of the treatment tanks represented an artificial irrigation lagoon and had its own regulated supply tap. Aeration was not provided to the tanks.

Each of the four treatment tanks was equipped with eight sheets of artificial substrate (Figure 2) to provide support for bacterial and algal communities. Substrate is crucial in assisting with settlement of water, development of bacterial biofilm (periphyton) which aids in nutrient processing (ultimately release of gaseous nitrogen to the atmosphere) and support for algal communities which 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. The fifth tank was filled with water only and was used as a storage/ acclimation tank for fish.

**Figure 1.** Groper Creek study site.

**Figure 2.** Artificial substrate in the treatment tanks.

Both header tanks were filled with lagoon water from a nearby irrigation canal (Figure 3) every 14 days via a water truck. Water flowed to each of the treatment tanks at a rate of 700L/day to give a retention time of 14 days.

**Figure 3.** Irrigation canal used to supply water for experiment.

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. The Fish species trialed were the detritivorous grey mullet (*Mugil cephalus*) at a density of 15/tank and the algae-eating striped scat (*Selenotoca multifasciata*) at a density of 4/tank. Initial average length and weight of mullet were 138 mm and 36.7 g respectively and for scats were 105 mm and 18 g respectively. Scats showed poor survival and were replaced with omnivorous banded grunter (*Amniataba percoides*) on the 2nd November 2001. Banded grunter were stocked at 4/tank and had average length and weight of 120 mm and 88 g respectively.

Nutrient sampling of incoming and discharged water took place 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).

In September 2001 it was noticed that general productivity in the tanks was poor, most likely due to the very low levels of influent nutrient from the irrigation canal. These low nutrient levels probably resulted from low rainfall and fertilisation application rates in the region at the time. 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. Subsamples of algae and aquamat were then analysed to calculate overall nutrient content. All nutrient analyses were carried out on a Lachat QC8000 flow injection analyser according to standard methods (QuikChem methods, 1996). We thank Rodger Wilkie and are indebted to him for volunteering to sample the system from July to November. Unfortunately the sampling program could not be strictly adhered to due to equipment shortage (shortage of sample bottles on site), particularly during the last month of the experiment (November). Nutrient data for the majority of November contains dissolved nutrient results only.

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

## Results

**Fish Data:** Growth of the mullet was about 12 per cent with the average weight increasing from 36.7 g to 41.3 g and length increasing from 138 mm to 160 mm. The associated removal of nitrogen, assuming a protein content 15% per fish (Lupatsch *et al*, 1998) was 110 mgN/fish, or 1.65 g/tank (Table 1). 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.

**Table 1.** 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:** The amount of macro-algae colonisation in both treatments was significantly different with the *minus* fish treatment showing prolific aquatic filamentous weed growth (Figure 4). The filamentous algae, which was identified as a *Rhyzoclonium* species, 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 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 duckweed growth occurred in the tanks.

**Figure 4.** Top: *Minus* fish tank. Prolific filamentous algae growth on surface and bottom of tank. Bottom: *Plus* fish tank. Aquatic weed growth has been confined to the substrate only. Note presence of phytoplankton bloom.

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 5). Mean phosphorous discharge from the two treatments was not significantly different from each other ($P>0.05$).

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 6). Analysis of Variance showed that 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 7). These discharge levels from both treatments were low highlighting 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. 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 organic compounds leached from the weed. Nitrogen discharged from the *plus* fish system was mostly phytoplankton and resuspended particulate material (Figure 4).

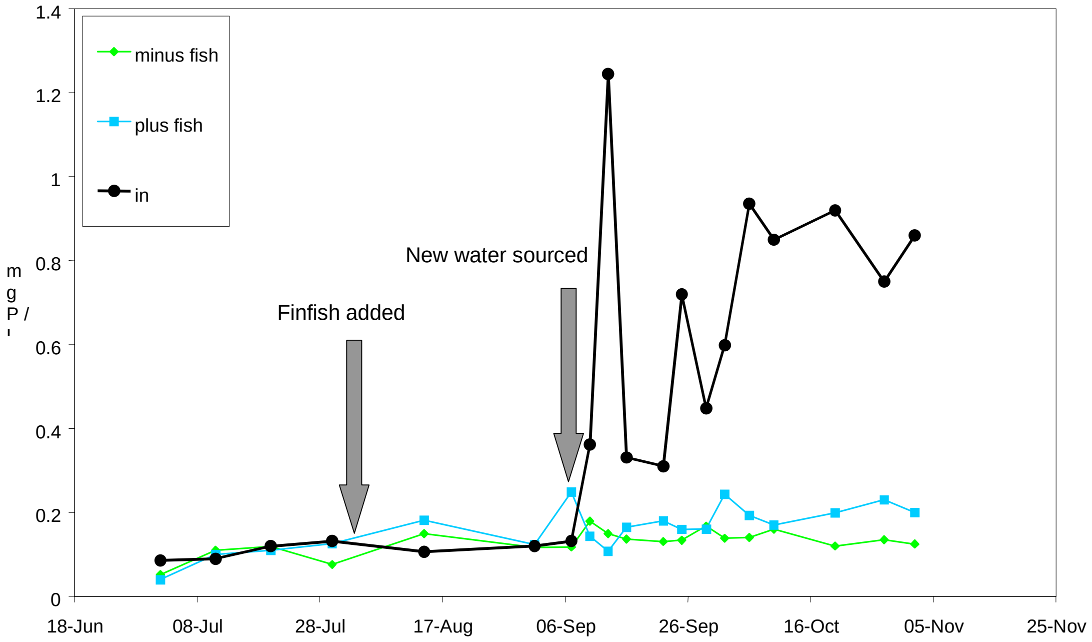

**Figure 5.** Total phosphorous profile for the *plus* and *minus* fish treatments over the experimental period.

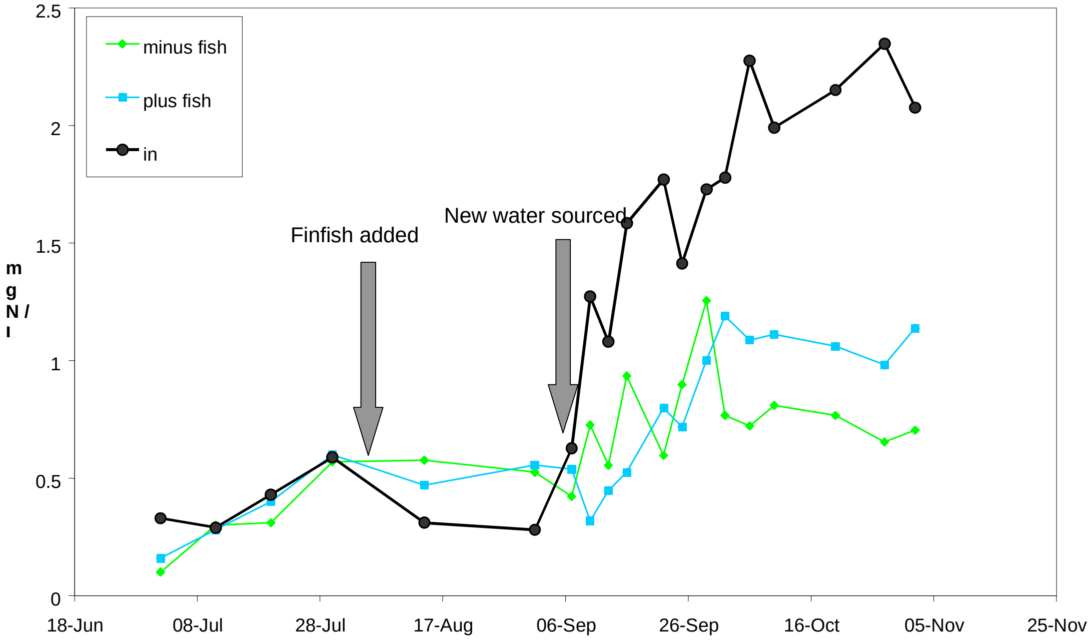

**Figure 6.** Total nitrogen profiles for the *plus* and *minus* fish treatments over the experimental period.

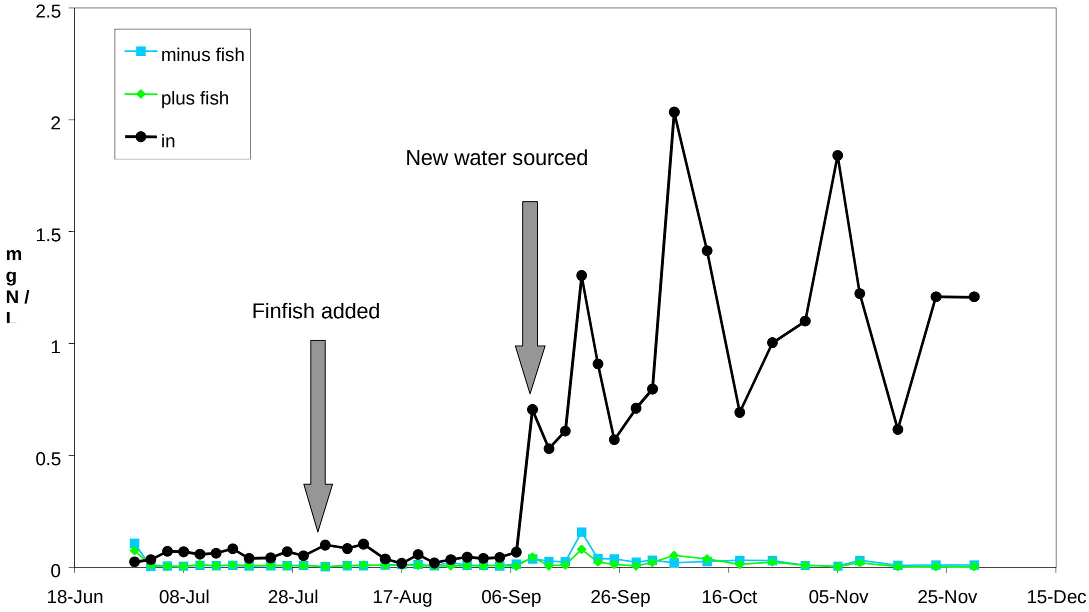

**Figure 7.** Dissolved inorganic nitrogen (DIN) profiles for the *plus* and *minus* fish treatments over the experimental period.

**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 somewhat different as evident in the overall nitrogen budget for the trial (Table 2).

**Table 2.** Calculated Nitrogen budget for the trial (all values ±10%).

| 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

Minor discrepancy exists in the derived nitrogen budget that can be attributed to the inherent errors in subsampling 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 unlikely 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 restricts denitrification by increasing the localised oxygen concentration within the substrate biofilm (Bitton, 1994). More likely is that the dense phytoplankton bloom witnessed in *plus* fish treatment during the last month of the trial 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.

## Conclusions and recommendations

The trial clearly demonstrated that finfish had a pronounced effect on the nutrient dynamics and algal growth in the simulated lagoon systems.

In the *minus* fish system, the majority of nutrients were stored in the filamentous weed. The remainder appeared to be discharged in the form of organic matter released by the algal community. Algal growth was so prolific that self shading death and re-release of nutrients was imminent. Unfortunately, the trial had to be terminated before this was observed. Presence of fish eliminated growth of aquatic weed on the surface and on the bottom of the treatment tanks. More algae grew on the artificial substrate but overall less aquatic weed growth occurred when the fish were present. In the *plus* fish system, nutrients not channelled into algal and fish growth were converted into phytoplankton and discharged.

Mullet assimilated some nutrient from cane farm lagoon water during the term of the trial; however, fish growth does not account for all of the reduction in filamentous algae apparent in the *plus* fish system. It is likely that reduced algal growth was also achieved via mechanisms other than direct consumption (eg. constant movement of the water column, surface skimming by the mullet) and/or low digestibility of the algae. The incorporation of a dedicated algavore (presently candidate species unidentified) may improve nutrient removal via direct consumption and assimilation of algal nutrients as well as provision of greater quantities of detritus, through excretion, for detritivores, eg. mullet.

The question now is: are the results transferable to a ‘real’ lagoon and how can nutrient removal be improved? Given that the physical water quality (i.e. dissolved oxygen, pH) in existing lagoons is poor due to excessive weed growth, it is unlikely that appropriate densities of fish could be supported without prior modification of the lagoon. If the lagoon is firstly cleared of existing weed and then stocked with mullet and some artificial substrate, it would be expected that aquatic weed growth would be confined to the substrate and to the sediment rather than the surface. Less weed would also be expected to grow relative to a lagoon with no fish. However, with mullet present, the water column should also have higher concentrations of nutrient in the form of suspended solids and phytoplankton. Inclusion of a greater range of species in the fish system (eg. herbivorous fish and freshwater invertebrates such as filter-feeding mussels) could improve overall nutrient assimilation through usage of all available food types and this may counteract the production of phytoplankton seen in the pilot trial.

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