Determining end-point goals and effective strategies for rehabilitation of coastal wetlands: examples from the Burdekin River, North Queensland

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Abstract

Rehabilitating coastal floodplain wetlands is the subject of significant government, industry and community investment. Restoring natural function to wetlands in a highly and permanently modified environment may not be realistic. Health and naturalness may be very different end-points for such wetlands, depending on the landscape context, creating the need for more holistic and expansive evaluations of end-point goals. Commonly, we find that the solutions proposed are often based on generic and simplistic views, including the reversal of the perceived root cause of the problem, though this is not always the best course of action. These simplistic views often result in unrealistic expectations and a failure to target the most effective outcomes and means of rehabilitation. This paper discusses three case studies where end-point goals for wetland rehabilitation are quite different from restoration of their pre-European state, and how elevated turbidity and flow regimes, even though unnatural and often thought of in a negative context, are actually maintaining the health of key coastal wetlands by decreasing their vulnerability to other human pressures. In each case, improved scientific understanding of what is the ultimate driving force of wetland health, and what should be the end-point goal, are being used to drive rehabilitation actions and achieve tangible results.

Keywords

Wetland rehabilitation, water hyacinth, Burdekin River

Introduction

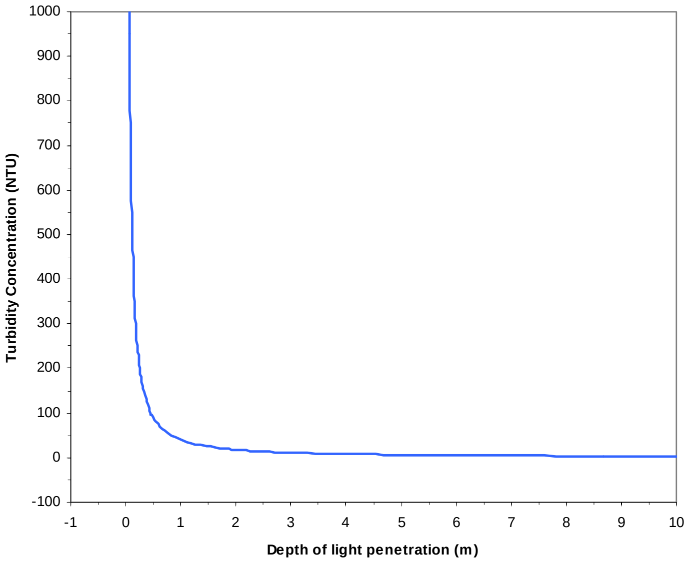
Approximately 80% of the naturally occurring wetlands on intensively developed floodplains of the north-east coast of Queensland have been destroyed, mostly for agricultural development (Burrows, 1998, Perna & Burrows, 2005). Most of the remaining 20% are in a perilous state, being impacted by aquatic weeds, poor water quality and loss of riparian vegetation, and they only support a fraction of the biodiversity and productivity that they are capable of and only a few of the wetlands and watercourses in these areas remain in good condition (Burrows, 1998; Tait & Perna, 2001). Against this background, wetland rehabilitation is a major area of natural resource management (NRM) investment in the region. In highly modified systems, deciding on what state any wetland should be returned to, and how to get it to that point, are major sources of debate. In most cases, returning the system to its natural state is simply not possible and in many cases, may not even be desirable. In such cases, rehabilitating the wetland to provide a healthy habitat, even if it differs substantially from its natural state, may be a more desirable goal. The differences between the goals of naturalness and health are considerable, both in terms of the environmental outcome, and the methods required to achieve those goals. This paper presents three case studies of wetlands within a highly modified agricultural setting, discussing the various approaches taken in their rehabilitation.

Case study examples

Three case study examples are from the lower Burdekin River, approximately 80km S of Townsville, north Queensland. Extensive irrigation, mostly for sugar cane, occurs on the 50km wide floodplain, with much of it utilising water from the Burdekin Falls Dam. This has resulted in substantial loss of wetlands, and significant alterations to the natural conditions of most of the remaining wetlands (Tait & Perna, 2001). Many of the aspects of water quality summarised here are discussed in more detail in Butler (2005).

Burdekin Falls Dam/Lake Dalrymple

Lake Dalrymple is a 1.8M ML water storage formed by construction of the Burdekin Falls Dam (BFD) in 1988. It captures 86% of the Burdekin's (133,000 km^2) catchment area. In the Burdekin catchment, wet season flows are generally highly turbid with a high proportion of fine colloids that settle very slowly, if at all. Under normal, pre-dam, high flow conditions, this turbid water would quickly be washed to downstream estuarine and marine environments. Hence, water in the unregulated Burdekin River is turbid for short periods after swift flows (mostly, but not always in the wet season) and then relatively clear for the remainder of the year. Being a strongly seasonal river, the rivers baseflow outside of the wet season is quite low. However, because the BFD now traps a large volume of turbid water (which would otherwise have passed downstream) and the colloids do not settle to any useful degree, the impoundment is persistently turbid all year round (Griffiths & Faithful, 1996, Burrows & Faithful, 2003). Water is released daily from the BFD for use by downstream irrigators, thus the river length below that dam is also persistently rather than episodically turbid. The dam is 159km upstream from the river mouth so a significant length of river is affected. Additionally, the turbid water from the river is also pumped into the extensive creek and wetland system on the floodplain for irrigation there, also increasing the turbidity persistence of many of these formerly clear waterbodies (Tait & Perna, 2001, Butler, 2005).



The change from relatively clear water to persistent turbidity obviously has some very significant ecological ramifications. An important point that applies to much of our following discussions is that as Figure 1 shows, ecological responses to turbidity are strongly non-linear. Large decreases to highly turbid water may not produce significant changes to light penetration whereas small changes to low turbidity water may have very large effects (including reducing the eutrophication potential of increased nutrient concentrations). Ecological effects are also dependent upon depth profile of the water body (i.e, whether changes to light penetration actually make any difference to the amount of light reaching the benthic zone).

Figure 1. Graphical representation of the effect of turbidity on light penetration (after Pearson *et al.*, 2003).

Two points to be made relate firstly to the impact of the ecological change, and secondly to the management response. Although the instream ecology of the Burdekin River downstream of the BFD has likely changed considerably, we are not aware of any obvious reductions in its health. Fish and macroinvertebrate abundances and diversity are as high as the non-regulated tributaries that flow into it, and there have not been any reported fish kills (unlike other watercourses in the region) (Brizga *et al.*, 2005). The Burdekin River responds to every runoff generating rain event by becoming turbid for a period of days to weeks, or even months, depending on the size of the event and extent of follow-up rains. The timing and frequency of these high flow events is unpredictable. The biota living there are adapted to regular and relatively unpredictable changes in flow and water clarity. We are not saying that no species have suffered reductions in their abundance since the change, only that by comparison to the health of most other ecosystems in the region (see later case study examples), the river is believed to be in better health. All the available data on the system was reviewed in detail by the expert panel convened for the Burdekin Water Resource Plan (Brizga *et al.*, 2005) who scored it poorly for its degree of departure from natural condition, but noted that it remained a more productive and useful habitat than most other watercourses on the Burdekin floodplain.

A common view we encounter amongst most involved in NRM in the Burdekin region, is that the turbidity of the dam is due to erosion coming from the rangelands upstream of the dam and that the solution to its persistent turbidity is to improve grazing land management – a not unexpected response. A flyover of the Burdekin rangelands shows that it is badly eroded in many places. SEDNET modelling (McKergow *et al.*, 2005) has shown that erosion has significantly increased since European occupation. However, the dams' turbidity is not caused by this increased erosion, but by the large amount of high flow event water, containing fine colloidal material of poor settling ability, stored in the BFD, compared to the low dilution capacity afforded during the remainder of the calendar year by clear incoming river flows (Griffiths &

Faithful, 1996; Butler, 2005). If the storage volume of the dam was less, and/or the volume of incoming clear waters during baseflow greater, there would be a much greater dilution capacity. The Charters Towers Weir ~100km upstream of the BFD clarifies in pace with the river upstream and downstream of it, as did the weirs downstream of the BFD before it was constructed. The only time we have observed the dam to clarify to any degree was after Cyclone Joy in 1991 when the post event and dry season baseflow volumes entering the dam were very high (ie, high dilution capacity). Thus land management won't solve this turbidity issue. It exists because the dam exists, and the effect is transferred downstream because water is needed to be released on a daily basis. Limnological monitoring shows that the water column is turbid throughout (Griffiths & Faithful, 1996, Butler, 2005) so multi-level off-takes won't solve it. We need to accept this as being the new state of the river below the dam. Where warranted, management actions could be taken to protect individual, formerly clearwater wetlands on the floodplain that now receive this turbid water. The following examples all receive water from the BFD and the turbidity of that water is part of their more complex management regime.

Sheep Station Creek

Sheep Station Creek is a delta distributory stream discharging flow from the Burdekin River during very high flow events, as well as having its own catchment area. It has been used to distribute irrigation water for many decades, though the level of development increased when the BFD made greater levels of water available during the early 1990's. Prior to artificial flow supplementation, the creek flowed seasonally or episodically, contracting to a series of discrete clearwater lagoons for most of the year (Perna, 2003). Now however, large volumes of turbid water are pumped from the Burdekin River into the creek and along its length for distribution to irrigators, creating perennial flow, elevated water levels, and a persistently elevated turbidity regime (Tait & Perna, 2001; Bird, 2004). In addition, the riparian vegetation has been lost in most places and the majority of creek bank length is now dominated by the exotic semi-aquatic paragrass.

The final addition that ultimately limited the ecological functioning of the creek was that virtually its entire water surface, was, for most of the 1990's, completely covered in water hyacinth. The mats became so thick that they could not be budged even by large floods, and were secondarily colonised by a variety of vines, grasses and even tree saplings. Despite the large volumes of pumped irrigation water passing underneath the mats, the waters there were dark and anoxic and supported no obvious plant life and only a limited range of anoxia-tolerant fauna (Perna, 2003). Under a multi-stakeholder community initiative, and combining various funding sources, from 2000-2004, the lagoons along the length of Sheep Station Creek were progressively mechanically cleared of the hyacinth mats using a combination of limited herbicide application, a floating weed harvester and a long-arm excavator equipped with a rake (Perna, 2003). The rapid and dramatic improvements in dissolved oxygen level (Perna & Burrows, 2005), a doubling of fish species diversity in the lagoons (Perna, 2003) and a return of water birds and native aquatic macrophytes (Bird, 2004), subsequent to clearing, testified to the programs success. Despite having a decimated riparian zone dominated by exotic grasses, high nutrient loading, and being surrounded by intensive agriculture, no fish kills have been reported in the system since it was cleared. An annual maintenance program has been established to control regrowth through herbicidal spraying of smaller mats before they become problematic. Given the large amount of aquatic habitat rehabilitated and converted to useful, productive ecosystems, rapidly and for relatively little cost, we rate this as one of the great wetland rehabilitation projects of the early Natural Heritage Trust years.

One of the more common comments we have received about this program is that the growth of the weed mats is probably enhanced by the unnaturally high nutrient loading and flow regime, and that the program should target the cause (altered environmental conditions including elevated nutrients), rather than the symptoms (removal of weeds). We accept the high nutrient loading, for which there is quantitative evidence (Perna & Burrows, 2005), but point out that BFD water contains moderate nutrient levels (soils in the dam catchment are fairly poor) so high nutrient loads in Sheep Station Creek result from constant inflow not elevated concentrations (Butler, 2005; Perna & Burrows, 2005). Thus reductions in nutrient loading would require substantial changes to the pumping regime of the creek and to how the surrounding irrigation operates. Moreover, recycling of sediment bound nutrients is also likely to be substantial. Overall, with nutrients in such excess, even if the extremely difficult task of obtaining very large reductions in nutrient losses from surrounding farms and upstream grazing lands were achieved, there would still be ample nutrients to enable rapid hyacinth growth. Introduction of a seasonal hydrological regime would impact upon the hyacinth mats but construction of an alternative method for delivering water to farms would costs millions of dollars, and as low water levels make waterbodies more prone to poor water quality (Butler, 2005), it is doubtful that this would improve their health anyway. In its pre-development state, the seasonal hydrology would have less impact than in its current highly modified condition. Whilst in the pre-development state, the system may have resisted hyacinth invasion, in its current state, it could not be made such. In this case, the only option was to treat the symptoms and remove the hyacinth mats. Using this approach, for a modest investment of ~$400K and annual maintenance of ~$25K, the system has been made productive and healthy for the last 6 years (Perna, 2003; Perna & Burrows, 2005; Bird, 2004; unpub. data).

Now that Sheep Station Creek is no longer dominated by hyacinth mats, its water quality responds to other factors, notably an interaction between flow rates, turbidity regime and growth of submerged macrophytes. When flow rates (ie, pump rates from the turbid Burdekin River) are high, turbid water flows along the entire creek length but during lower flow (pump) rates, the water clarifies to varying degrees as it progresses downstream. Thus the upstream lagoons are persistently turbid but the downstream lagoons vary between turbid and partially clear, depending on flow rates. During periods of greater clarity, substantial stands of submerged aquatic macrophytes form. Bird (2004) studied the water quality of several lagoons along an upstream-downstream gradient within the creek and found that the dissolved oxygen status (the most important water quality parameter for assessing health in tropical coastal lagoons) of the upstream lagoons was higher and more stable than for the downstream clear lagoons where excessive macrophyte growth was fuelling significant diel oxygen cycling. With such high submerged plant biomass, the sudden appearance of turbid water when pump rates increase can rapidly increase respiration rates, creating poor water quality conditions, whereas a more gradual appearance can limit this effect. With some research to determine the most appropriate regime, the ability to control flow rates and turbidity regime via the pumping regime provides an opportunity to manipulate the system to maximise its health and productivity. Thus, the artificial flow regime is both part of the cause of the problems in this creek system, but also part of the solution.

Overall, supplementation to the creek provides increased amounts of permanent aquatic habitat, constant flushing and dilution with water that is far better quality (moderate nutrients, good dissolved oxygen, no agrichemicals) than the agricultural runoff the creek would otherwise be dominated by. Supplementation promotes re-aeration and mixing and provides enough turbidity to moderate growth of potentially problematic submerged macrophytes and limit eutrophication responses to elevated nutrient levels. Currently, pump rates and timing are based on irrigator demand, but research into environmental responses would further enhance the rare opportunity provided here to maintain wetland health in an intensively developed floodplain. Basically the water is an environmental flow and the supplemented creek has much greater potential to contribute to regional productivity than it did in its natural state, so is making up for some of the wetland losses that have occurred in the region.

Barrattas Creek

Barrattas Creek is a separate coastal catchment on the Burdekin-Haughton floodplain. During very large flood events, its lower reaches may distribute floodwaters from the Burdekin River. The upper catchment is cattle grazing land, as was the lower half until the development of the irrigation scheme associated with construction of the BFD. During this development, a wildlife corridor was left along the Barrattas Creek, generally about 1km either side of the creek. Although this corridor has suffered several negative influences from the surrounding irrigation area and is not without threatening processes itself (inappropriate fire regime, weeds etc.) and appears to be slowly degrading, it currently retains considerable riparian integrity (Tait & Perna, 2001; Davis *et al.,* 2005), certainly more than any other stream in the irrigation scheme and nearby developed areas. The riparian areas are in fact, quite attractive, and provide a diverse plant assemblage with high levels of bank structure, fallen timber and riparian shading to the stream.

With the development of the irrigation scheme, water released from the BFD is pumped from the Burdekin River to irrigators in the Barrattas catchment (though some irrigators use groundwater). Most farms are flood irrigated and a large volume of tailwater exits the flood rows and discharges into the Barrattas Creek system. The Barrattas Creek system was naturally seasonal, drying back to a series of clearwater waterholes, some of which are quite large, especially in its lower reaches. Now because of the large volumes of tailwater coming off the farms, its runs year-round, mostly with relatively turbid water (turbid due to it source – the BFD, not because of farm erosion), representing a significant change to the creeks hydrology and ecology.

We commonly field suggestions that the hydrology and water clarity regime of the system be returned to its pre-development state. In an era of greater water-use efficiency, the tailwater entering the creek system is seen as wasted, and schemes to encourage and subsidise greater tailwater recycling have been implemented.

This is seen and promoted as a win-win situation where water-use efficiency is increased and the return to a more natural flow regime is being progressively implemented that will 'improve' the health and condition of the creek system. We do not agree with the full implementation (i.e. return to a pre-development flow regime) of this proposition. Barrattas Creek is, like the Burdekin River, quite healthy in the sections where perennial flow is occurring (Davis *et al.,* 2005). Even with the success of the Sheep Station Creek rehabilitation project, we consider that system is still not as healthy and productive as the current state of the Barrattas Creek system. Although a sad indictment on the management of the regional streams, Barrattas Creek is the only major watercourse in the entire coastal region between the Proserpine River, ~150km S and the Herbert River ~150km N, that has no fish passage barriers. With increased availability of good condition habitat, and no passage barriers, Barrattas Creek now provides a major regional freshwater nursery for desirable species such as barramundi and mangrove jack (unpub. data), that compensate for the extensive losses of their habitats elsewhere in the region. Although whilst under pre-development conditions, Barrattas Creek supported several major deep, waterholes, many other waterholes would have suffered considerably from stagnation as normally occurs in seasonal and ephemeral dry tropics creeks. These waterholes were likely oligotrophic with much lesser productivity than the existing supplemented stream.

The Barrattas water quality monitoring dataset (unpublished) is probably the most extensive for any river in northern Queensland. It shows that agricultural contaminants are delivered as a series of high concentration pulses. At times, concentrations of ammonia and BOD are high enough that they would normally cause major fish kills but currently this does not happen because the constant flows provide re-aeration (increasing dissolved oxygen and preventing pH from rising to levels where ammonia would become acutely toxic) and also flushing and mixing, diluting and dispersing the effects of harmful contaminants (Butler, 2005). The BFD is not fully utilised and has ample spare capacity to allocate to environmental flows. We are of course strongly in favour of greater water use efficiency. However, in a region where most freshwater wetlands have been lost and most of the remainder are in very poor condition, we would argue that using some water from the BFD to maintain a perennial flow regime and increase habitat availability, even though artificial, is a worthwhile use of this water as an environmental flow. For us, the question is not one of returning the system back to its pre-development flow regime, but what is the minimum level of water and rate of flow required to prevent the system suffering the ill effects of stagnation and other water quality problems that would reduce its health and productivity. Currently, the tailwater coming off the farms, although not perfect in its quality, is boosting the systems productivity, and is essentially provided as a free environmental flow. An even better result would be obtained by replacing tailwater with environmental allocations direct from the BFD as this water contains less contaminants, especially farm contaminants (Butler, 2005). Barrattas Creek was not however, included in the Burdekin Water Resource Plan (Brizga *et al.,* 2005) and all Queensland water resource plans have the pre-determined generic goal of mimicking natural flow regimes, not allowing for situations where non-natural flow regimes would provide the greatest environmental benefit. In the meantime, the better management options for Barrattas Creek would be to focus NRM efforts on reducing aquatic weed infestations and maintaining and improving the health of the riparian zone, especially in the seriously degraded tributaries of Barrattas Creek outside of the wildlife corridor.

Conclusion

The examples provided here show how in highly modified agricultural settings, a 'horses for courses' approach, backed by a scientific understanding of wetland drivers, has resulted in the pursuit of health over naturalness. In less modified settings, restoring naturalness is more likely to be the appropriate management goal. In these examples, consideration of the rehabilitation goals has also been taken in a regional context rather than in isolation, in order to maximise and compensate for, lost regional wetland functions. Restoring the natural functions of a wetland may not be possible, or even desirable, if all those around it have been lost or are highly modified. If there are only a few wetlands remaining in a landscape that once housed many, those few cannot be expected to perform all of the functions the pre-existing wetland complex would have done, and they may even be required to perform some of the functions lost from other wetlands. In this sense, they can act to compensate for losses elsewhere. Even artificial wetlands can become valuable habitats, as evidenced by the many impoundments listed in the Directory of Important Wetlands in Australia (Environment Australia, 2001). The rehabilitation options either adopted or recommended in this paper are designed to maximise the environmental gains from the existing landscape setting for the limited budgets available, thus maximising environmental bang for the buck. The dramatic improvements shown in these programs on the Burdekin floodplain, for limited cost, illustrate the success of this approach.

We must point out that our rehabilitation ideas are specific to the case studies presented in this paper and may not be applicable elsewhere. The elevated flow and turbidity regimes discussed in this paper actually reduce vulnerability to all the pressures currently being experienced by the streams in these case studies. BFD water contains moderate nutrients and no agrichemicals, and its waters provide dilution and mixing, and flush away contaminants that may enter these creeks from surrounding agricultural and urban land (Butler, 2005). The ability to use environmental flows from BFD provides management options for these wetlands that don't exist elsewhere. This advantage should be utilised to maintain selected aquatic habitats in good health and productivity to compensate for the substantial loss of wetlands elsewhere in the region.

The overall message is that although we can manage their impact to some degree, feral and domestic livestock, human land and water uses and invasive aquatic weeds will always be present in these modified landscapes. The contemporary landscape is so different to the pre-european version that most wetlands would not fare well if returned to their previous state (even if that were somehow financially and logistically possible). Far better ecological outcomes can be achieved by making modifications that help them cope with the existing pressures that are unlikely to ever be fully alleviated.

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