

Chapter 2

Review of existing ecological knowledge of the Lower Gwydir aquatic ecology

2.1 Introduction

The Lower Gwydir floodplain wetlands are a high conservation-value aquatic ecosystem in north-western New South Wales (Kingsford, 2000). However, despite the number of past studies on various aspects of these wetlands, there are few qualitative or quantitative scientific data available, including relationships between ecosystem function or biotic integrity and flow variability. Past reports focus mainly on three aspects of the wetland ecology, namely water quality issues, wetland flora and water birds. Apart from fishes, there is little information on other faunal components. Other important components of the ecosystem that form the base of most aquatic food webs (algae, micro- and macroinvertebrates) are hardly described at all, probably either due to reasons of taxonomic or technical difficulties or a general lack of interest in these groups. Furthermore, there is little knowledge on possible impacts of the extensive hydrological alteration that the Gwydir River ecosystem has experienced, with the exception of changes in plant and water bird communities.

This chapter provides an overview of the current knowledge of the ecology of the Lower Gwydir wetlands. We are aware that this review is by no means exhaustive and does not contain all available information on the Lower Gwydir wetlands. The large amount of 'grey literature' is often difficult to locate, often due to organisational changes in stakeholder groups or agencies. However, we provide a representative overview of what is known (and especially what is not known) of the Lower Gwydir wetlands and their ecological components.

2.2 Hydrology and water quality

Rainfall seasonality and Hydrology. The Gwydir valley experiences a summer-dominant rainfall pattern, with more than 60% of the annual rainfall received between November and March (ANRA, 1995; McCosker *et al.*, 1999). During this time, rainfall is received from summer thunderstorms while the southward movement of tropical rain depressions from Queensland can result in heavy rainfalls and cause significant floods. A shorter wet period may also occur in June and July, when approximately 15% of the annual rainfall is received (McCosker *et al.*, 1999). This winter rainfall can also cause flooding such as in 1998 (McCosker, 1999). However, flooding at this time of the year occurs less frequently than in summer.

Spatial patterns of mean annual rainfall vary throughout the Gwydir catchment, increasing towards western end of the wetlands (BOM, 2007; Keyte, 1994), and so flooding of the Lower Gwydir floodplain is dependent upon flows from middle and upper regions of the catchment.

Across the Lower Gwydir floodplain, mean annual rainfall varies from less than 450 mm to the west to 585 mm around Moree to the east. However, construction of the 1,364,000 ML Copeton Dam in 1976 and the subsequent expansion of irrigated agriculture downstream has considerably altered flow and hydrological patterns into most Lower Gwydir channels (Mawhinney, 2003; Schalk, 2006). Copeton Dam regulates approximately 55% of inflow into the Gwydir River (Keyte, 1994), and re-regulating structures at Tareelaro, Boolooroo and Tyreel divert flows from the Gwydir River into the Mehi River, Carole Creek and Lower Gwydir River/Gingham Watercourse, respectively.

Recent analyses of observed and modelled daily flow data have shown the Gwydir to be one of the most flow-altered rivers in the northern Murray-Darling region (Sheldon *et al.* 2000; Grouns 2008). There has been a decrease in the frequency and magnitude of flooding in the wetlands (Keyte, 1994). The frequency of moderate and large (and zero flow) events has decreased, while the percentage of flows of <100 GL per annum has more than doubled (Sheldon *et al.* 2000). Mean annual flow at the Yarraman bridge gauging station has fallen from 610 GL in an unregulated situation to 116 GL in 1993/94 (McCosker *et al.*, 1999). River regulation has also altered patterns of flow seasonality in the Gwydir River. For example, rises in winter flow have disappeared (McCosker *et al.*, 1999). Under pre-development conditions, the core wetland areas were flooded 17% of the time over 93 years, but now flooding occurs only 5% of the time due to diversions and a 70% reduction in flows large enough to reach the Gwydir wetlands (Keyte, 1994; Kingsford, 2000). Furthermore, since the development of irrigated agriculture in the region, the amount of water harvested from unregulated flows (off allocation access) has also risen.

The main impact of Copeton Dam has been the reduction in major flood events that would otherwise inundate extensive areas of the Lower Gwydir floodplain, a reduction in river flows during non irrigation times and a higher than usual flow in times of irrigation water delivery (Bennett & Green, 1993; Montgomery & Faulkner; Schalk, 2006). Small unseasonal floods are typical for regulated rivers in the Murray-Darling catchment (Chong & Ladson, 2003).

Water quality. Water quality data available for the Gwydir River catchment have mainly been summarised in two recent reports by the NSW Department of Infrastructure, Planning and Natural Resources (NSW DIPNR, 2002; Mawhinney, 2005). Research has also examined the impact of the irrigation industry on water quality in Gwydir watercourses (Montgomery & Faulkner, 2002). There are also data scattered through a multitude of reports on various aspects of the Gwydir catchment. All these are summarised in the following sections of this document. As there is only anecdotal information available on the water quality in the Gwydir catchment prior to intensification of agriculture, we can only speculate on the overall changes in water quality in a historical context. Data from the above-mentioned reports date back to the early 1990s, and so temporal analyses of water quality focus on the past 15 years.

The NSW Department of Water and Energy and its predecessors monitored water quality parameters in 20 sites within the Gwydir catchment. As this review focuses on the Lower Gwydir floodplain and associated wetlands we will concentrate on four selected sampling stations, namely the Gwydir River at Gravesend (above major irrigation abstraction), the Gwydir River at Yarraman, the Mehi River at Moree (main area of irrigation), and the Mehi River at Bronte as a comparison site at the end of the catchment. Water quality guidelines for healthy water for the environment, domestic and irrigation use are laid down by the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC & ARMCANZ, 2000). Since construction of Copeton Dam in the upper reaches of the Gwydir River, the

hydrologic and water quality variables have been closely linked to water released from the dam. Changes in water chemistry due to the release of hypolimnetic water from Copeton Dam will have the most pronounced impacts on mid sections of the Gwydir River below the dam. Besides water temperature, hypolimnetic water can have significantly different water chemistry characteristics in comparison to natural river discharge (McCosker *et al.*, 1999). Hypolimnetic water is often oxygen depleted, and may significantly reduce rates of photosynthesis and the accumulation and microbial breakdown of organic matter in deeper pools (Speas, 2000).

Water chemistry. An increase in salinity levels of freshwaters is a major concern in many parts of Australia. Water with high salinity levels is detrimental to the environment, unsuitable as drinking water and lastly can be unsuitable for irrigation purposes. Salinity is closely linked to river flows, as higher flows will dilute salt concentrations (Montgomery & Faulkner, 2002). However, higher flows will still increase the total salt load and, therefore, net export into downstream reaches even though the actual salt concentrations might be reduced (Mawhinney, 2005).

While there has been a general reduction in average salinity levels in most monitoring sites within the catchment during the last 15 years, median EC concentration still exceed the $350 \mu\text{S cm}^{-1}$ ANZECC trigger level for the protection of aquatic ecosystems in lowland rivers. However, salinity levels were below the threshold for irrigation use ($650 \mu\text{S cm}^{-1}$) at most of the monitoring sites (NSW DIPNR, 2002; Mawhinney, 2005). This can be seen as an improvement to the situation in the 1990s. Even though salinity levels satisfied ANZECC standards at that time, the salinity levels would have been too high to meet environmental standards of the 2000 ANZECC guidelines.

The Borders Rivers/Gwydir Catchment Management Authority (CMA) set an EC target at the lower end of the catchment (Mehi River at Bronte) at $390 \mu\text{S cm}^{-1}$, which should not be exceeded more than 50% of the time for continuous monitoring. In the 2003/04 monitoring season, this limit was exceeded 85% of the time. Furthermore, salinity trigger levels were breached 80% of the time in the Lower Gwydir River at Yarraman (Mawhinney, 2005).

Even though, there has been a significant improvement in salinity levels in the majority of monitoring sites in the Gwydir catchment in a historical context, the majority of sites still regularly exceed EC trigger levels for the protection of aquatic ecosystems. Due to a dilution effect, salinity levels are regularly lower during irrigation releases (Montgomery & Faulkner, 2002).

Acidity and alkalinity levels were within the ANZECC guidelines for most sampling occasions in all the monitoring sites. A pH threshold of 9 was exceeded only in a single instance and pH was never below the critical threshold of 6.5 for any of the measurements in 2003/2004 (Mawhinney, 2005).

Dissolved oxygen levels depend on a multitude of biotic (photosynthesis, microbial activity) and abiotic (temperature, salinity) factors and will vary over diel, daily and seasonal cycles. As with pH, oxygen concentrations usually fell within the ANZECC guidelines (120-60% saturation), hypoxia (< 60%) although was measured only occasionally in each of the sites (Mawhinney, 2005; Montgomery & Faulkner, 2002). However, as measurements were presumably taken during daylight, we cannot exclude the possibility that hypoxia might be problematic for aquatic organisms during night-time when photosynthesis ceases and assimilation processes are at their maximum.

Turbidity and sediments. The probable increase in turbidity due to changes in land management practices since European settlement, and subsequent flow regulation following construction of Copeton Dam is likely to have had a pronounced effect on sedimentation rates in the Lower Gwydir wetlands. Keyte (1994) reported extensive trapping of sediments in the dam in 1972 and pointed out that the generally high sediment loads delivered to the wetlands might be responsible for the low incidence of open water in the Gwydir floodplains (Keyte, 1994). Nevertheless, it is likely that Copeton Dam has also trapped a significant sediment load that would have otherwise been transported into at least the middle reaches of the catchment.

As in most Australian lowland rivers, turbidity is a natural feature of the Lower Gwydir River system, caused by suspended clay particles. There tends to be a downstream increase in turbidity due to cumulative effects of soil erosion in the catchment and localized riverbank and channel erosion (McCosker *et al.*, 1999). Irrigation releases from Copeton Dam can have steep ascending and descending limbs of their hydrograph, potentially intensifying channel erosion, destabilising riverbanks, and increasing water turbidity. Moreover, higher sediment loads can alter sedimentation rates in areas of sediment deposition. The increase in turbidity can have multiple environmental effects, including a decrease in water temperature, changes in water chemistry and nutrient loads (Guy & Ferguson, 1970), loss in primary production due to shading, reduction in foraging success of fish (decrease in visibility) (Miner & Stein, 1993), and interference of suspended material with the respiratory organs of fish and invertebrates (Berkman & Rabeni, 1987; Ryan, 1991). McCosker (1998) identified erosion issues in the Gingham Watercourse, with landholders recognising this as a priority management issue. The steeper gradient in the eastern part of the Gingham Watercourse seems to result in greater erosion rates and a deepening of the channel. This, in turn, prevents spill-over of water at flows that would previously have been sufficient to produce overland flows and provide wetlands with vital water (McCosker, 1998). Some of the problems have been remedied since construction work on the Gingham Watercourse.

Similar to salinity, turbidity is closely linked to river flow. For most of the measuring stations, there was a pronounced reduction in median turbidity levels between 2001-2004, as compared to the 1990s (Mawhinney, 2005). Besides interannual fluctuations in turbidity levels, there are rises in turbidity levels during irrigation periods (Montgomery & Faulkner, 2002). Furthermore, turbidity levels seem highest during times of pre-watering of irrigation fields. Turbidity levels frequently breach ANZECC guidelines during the irrigation and pre-watering season. During low-flow periods outside the irrigation season, turbidity is usually below ANZECC trigger levels (Montgomery & Faulkner, 2002). Turbidity levels varied between monitoring sites, with turbidity levels remaining below the ANZECC trigger levels for the Gwydir River at Gravesend and Yarraman, and the Mehi River at Moree. However, at the downstream end of the system, turbidity levels frequently exceed ANZECC guidelines for lowland rivers at the Mehi River site at Bronte (Mawhinney, 2005).

Anecdotal evidence suggest that turbidity levels may have been considerably lower in most parts of the Gwydir River system prior to agricultural intensification as witnesses recall being able to see the bottom of even deep waterholes in the Gwydir River and being able to observe fish behaviour in the clear water (Copeland *et al.*, 2003). An increase in turbidity and sediment load with land use and climate change is a well documented phenomenon in other Australian systems (Leahy *et al.*, 2005; Lu, 2005).

Nutrients. High nutrient loads in Copeton Dam potentially affect nutrient concentrations in water in the Lower Gwydir channels. Bennett (1996) reported elevated phosphorus levels in

Copeton Dam and points out a correlation between phosphorus levels in the Gwydir and discharge events from Copeton Dam (Bennett, 1996; McCosker *et al.*, 1999). Increased nutrient loads are often associated with blooms of blue-green algae and changes in species composition of plankton and macrophyte communities (Dent *et al.*, 2002).

There was no major change in nutrient concentrations in the majority of sites between the 1990s and the 2003/2004 monitoring season (Mawhinney, 2005). Most median phosphorus concentrations at sampling stations were close to or exceeded the ANZECC trigger value in lowland rivers (0.05 mg L^{-1}) and were not limiting to algal growth (Mawhinney, 2005). Total phosphorus and nitrogen concentration exceeded ANZECC guidelines in the majority of sampling occasions. Nutrient loads are frequently higher during irrigation and pre-watering times (Montgomery & Faulkner, 2002) while meeting ANZECC standards in the non irrigation seasons. This increased nutrient load during the irrigation season is presumably a result of higher flow events associated with increased runoff and probably intensified fertilizer use during the growing season. This could also reflect the release of nutrient enriched water from Copeton Dam during irrigation season as concentrations of total nitrogen are also elevated in the Gwydir River upstream of the main irrigation areas (Montgomery & Faulkner, 2002). There was, however, a pronounced increase in the phosphorus loading downstream of the irrigation areas. Phosphorus is frequently the limiting factor preventing algal growth, and this could potentially generate future problems with algal blooms in the system.

The Lower Gwydir floodplain wetlands function as a natural nitrogen sink, as nitrogen loads decrease towards the lower end of the floodplain (Montgomery & Faulkner, 2002). Wetlands are often seen as effective natural nutrient sinks (Mitsch & Gosselink, 2000).

Pesticides. Overall, the incidence and concentration of pesticides appears to have decreased in Lower Gwydir water samples over the last 10-15 years (Mawhinney, 2005). No pesticides were detected in the Gwydir River at Gravesend in 2001/2002, although herbicides were detected at the Gwydir River at Yarraman (NSW DIPNR, 2002). Insecticides and excessive levels of atrazine were encountered in all three monitoring sites at the end of the catchment, including the Mehi River at Bronte. Several pesticides were common in samples in 1991/92 as reported by Keyte (1994). Furthermore, during storm events, extremely high pesticide concentrations were observed (Keyte, 1994), with endosulfan reaching toxicity levels for fish. Concern was raised at the possibility of an accumulation of pesticides in the terminal wetlands that act as a sediment sink. Sampling at Brageen Crossing in 1992/93 detected two insecticides and five herbicides, with endosulfan being the most frequently detected pesticide (60% of all samples) (Keyte, 1994).

The number of samples contaminated with pesticides decreased significantly between 1991 and 2004, possibly result of improved management practices. However, all the monitored pesticides are still occasionally detected (Mawhinney, 2005). Furthermore, even though median atrazine levels are well below ANZECC levels, occasionally there are excessive levels. These high concentrations of atrazine are still of concern and might negatively affect the aquatic ecosystem.

2.3 Algae and in-stream vegetation

We are not aware of scientific information regarding algal growth and instream vegetation in the Lower Gwydir channels. Considering the turbidity of the rivers and the shading by

riparian vegetation by eucalypt and river cooba trees, submerged macrophytes are unlikely to be abundant and will be restricted to the edges of river channels. Species such as *Valisneria*, *Ludwigia* and *Typha* are known to occur in some channel areas such as the downstream reaches of the Gingham Channel. Additionally, the floating macrophyte water hyacinth (*Eichhornia crassipes*) is common in the open sections of the Gingham Watercourse and associated water holes. There is no information available on the phytoplankton community in the Lower Gwydir streams, although it might be similar to the Murray River that is characterised by cyanobacteria blooms in summer and diatoms in winter and spring (Shiel *et al.*, 1982). Phytoplankton biomass is sparse, as a result of the high turbidity. Attached algal growth in the Lower Gwydir floodplain will be restricted to suitable substrates such as coarse woody debris or areas of consolidated bank and again by light availability within the photic zone (Burns & Walker, 2000; Sheldon & Walker, 1997). We would expect that heterotrophic biofilms would predominate in large parts of the Lower Gwydir catchment due to turbidity and, thereby, low light availability for photosynthesis (Burns & Ryder, 2001).

In the Murrumbidgee floodplain, high flow events affect species diversity and biomass of biofilm, and environmental flow releases have direct impacts on instream productivity (Ryder *et al.*, 2006). Autotrophic biofilm production is an important energy source for higher trophic levels in floodplain rivers (Thorp & Delong, 2002). Water velocity directly affects biofilms through scour, and hence shapes benthic algal communities and functions (Peterson & Stevenson, 1992). Disturbance by flooding is one of the most important regulators of spatio-temporal variability in benthic communities in streams (Davis & Barmuta, 1989). As velocity and scour increase with increased flow, environmental flows should attempt to maximise biofilm productivity and biodiversity. Additionally, biofilms are ideal bioindicators to assess effectiveness of management due to the short generation time, sessile nature and responsiveness to environmental conditions and standardised methodologies for monitoring biofilms (Burns & Ryder, 2001).

2.4 Floodplain vegetation

The Lower Gwydir Valley floodplain comprises 220,000 ha of wetland and floodplain woodlands (Bennett & Green, 1993). Approximately 82% of this area is dominated by coolibah woodlands. The remaining area, due to its flat terrain and comparatively low elevation is subject to extensive shallow flooding. The period of inundation in these areas may last for several weeks or even months. These intermittent and semi-permanent wetlands occupy an area of approximately 24 000 ha. The dominant vegetation type is water couch (*Paspalum distichum*) in association with various species of rushes (*Eleocharis sp.*). In the wettest parts of the floodplain, marsh club rush (*Bulboshoenus fluviatilis*) occurs in large stands (Bennett & Green, 1993). The largest stand of 600 ha is believed to be the largest stand in New South Wales (Keyte, 1994).

Vegetation patterns. A baseline vegetation survey conducted by the University of New England established that the extent, floristic composition and community structure of vegetation on the Lower Gwydir floodplain is strongly linked to the elevation and pattern of inundation over time (McCosker *et al.*, 1993). As part of this survey, seven land units were identified across the floodplain, and these were then grouped into three main classes based on their elevation and associated pattern of inundation. The main classes were:

- Watercourse: Core wetland and watercourse land units;

- Low floodplain: Flood channel, sand monkeys and floodplain land units; and
- High Floodplain: High floodplain and ridge land units.

The “watercourse” lies in close proximity to the end of the Lower Gwydir River channel and traditionally this area was inundated on an almost annual basis (Table 2.1). On grey clay soils, water couch (*Paspalum distichum*), tussock rush (*Juncus aridicola*) and ribbed spike rush (*Eleocharis plana*) are the dominant species. On black soils at the end of the Lower Gwydir sediment delta, marsh club rush (*Bulbshoenus fluviatilis*) is found in two large stands, the largest being 600 ha on “Old Dromana” (Keyte, 1994). Dead coolibahs (*Eucalyptus coolabah*) are a feature of these low lying sections of the floodplain. Their death has been linked to prolonged inundation following floods in 1955 and the 1970s, and compounded in the 1970s by major water releases from Copeton Dam during modifications to the spillway (Keyte, 1994).

The “low floodplain” is slightly higher in elevation and experiences less frequent inundation than the watercourse area (Table 2.1). Water flows into this area during moderate floods, usually about one in every four years. Soils tend to be predominantly heavy, self-mulching, cracking grey clays. Coolibah woodlands are the dominant vegetation community with a sparse understorey of lignum (*Muehlenbeckia florulenta*) and a groundcover of Warrego summer-grass (*Paspalidium jubiflorum*). In the water channels that cut across the low floodplain river cooba (*Acacia stenophylla*) and lignum grow along the banks (McCosker & Duggin, 1992).

The “high floodplain”, due to its elevation is infrequently inundated (Table 2.1). Because inundation in these plant communities is so rare, they are not considered as a floodplain ecosystem (Keyte, 1994). The vegetation occurring in these areas appears to be strongly associated with soil type. Red duplex soils occur at the highest elevation and poplar box (*Eucalyptus populnea*) is the dominant overstorey species, with a mixed sub-stratum of wilga (*Geijera parviflora*), white cypress pine (*Callitris glaucophylla*), leopard wood (*Flindersia maculosa*), with whitewood (*Atalaya hemiglauca*) and rosewood (*Heterodendrum oleifolium*) occurring on soils with slightly finer texture. Ground flora is normally sparse and comprises spear grass (*Stipa sp.*), windmill grass (*Chloris truncata*) and annual forbs (McCosker & Duggin, 1992).

In areas with grey clay soils, coolibah, myall (*Acacia pendula*) and briar (*Acacia farnesiana*) occur forming open woodland communities. Belah (*Casuarina cristata*) is commonly found interspersed with coolibah. Ground cover comprises Queensland blue-grass (*Dichanthium service*) and curly windmill-grass (*Enteropogon acicularis*) though increasingly these perennial grasses are being replaced by annuals and naturalised *Medicago* species (Keyte, 1994).

Impacts of flooding and altered flow regime on wetland vegetation. The changes to the natural hydrological regime are thought to have placed considerable pressure on plant communities of the Lower Gwydir wetlands that have evolved under a regime of more frequent and longer lasting periods of inundation. Changes in the flow regime are believed to have two major impacts on these wetlands. Firstly, the abundance of plants more commonly found in true terrestrial assemblages is increasing in many wetland plant communities; and secondly, some introduced plant species such as lippia (*Phyla canescens*) are spreading at an alarming rate as they appear to cope more successfully than native species under environmental conditions associated with the altered flow regime.

Table 2.1. Approximate flooding regime of the major vegetation communities in the Lower Gwydir floodplain before river regulation [adapted from McCosker & Duggin, (1993)].

Distinguishing species	Ecological management unit	Flood frequency	Type of flood event
coolibah, <i>Eucalyptus coolabah</i>	Floodplain	1 in 10-20 years	Major floods
river cooba, <i>Acacia stenophylla</i> lignum, <i>Muehlenbeckia florulenta</i>	Low floodplain	1 in 3-7 years	Moderate/major floods
river red gum, <i>Eucalyptus camaldulensis</i>	Gwydir overflow (vicinity of raft)	1 in 2-3 years	Minor/moderate/major floods
water couch, <i>Paspalum distichum</i> ribbed spike-rush, <i>Eleocharis plana</i> tussock rush, <i>Juncus aridicola</i>	Watercourse	1 in 1-2 years	Freshes, minor/moderate/major floods

The reduction in the frequency of inflow into the wetlands has had the greatest impact on the land units within the “Watercourse”. The plant communities in this area have evolved under a hydrological regime of regular flooding. Evidence is presented by Keyte (1994) that, based on aerial photography between 1974 and 1992, the area of marsh club rush had contracted to one third its original size. The semi-aquatic and aquatic vegetation in the core and watercourse land units is being gradually displaced by terrestrial species such as black roly-poly (*Sclerolaena muricata*), blown grass (*Agrostis avenacea*), scotch thistle (*Cirsium vulgare*) and lippia (Keyte, 1994). Vegetation communities in the peripheral intermittent wetlands of the “low floodplain” appeared to have been less affected by reduced frequency of inundation as they are capable of withstanding periods of up to 10 years without flooding (Keyte, 1994).

Lippia is considered a serious threat to Lower Gwydir wetland plant communities. It occurs in areas subject to frequent inundation. It possesses a deep taproot to access moisture during dry periods and can be spread both by seed dispersal and vegetative mechanisms. As it grows, it tends to smother native species such as water couch. It has very limited grazing value to stock and reduces the carrying capacity of paddocks where it dominates.

The dynamics of plant communities can be influenced strongly by the pattern of inundation (McCosker, 1999; McCosker *et al.*, 1999). Both the timing and depth of inundation have an impact on the growth patterns of key native wetland species and weeds species such as lippia. Marsh club-rush responds to inundation during winter and spring by successfully flowering and setting seed which provides opportunities to maintain genetic diversity in the species and offering more opportunities for survival (Rea, 1994). Inundation from late summer floods, while promoting vigorous vegetative growth, did not result in seed set (McCosker, 1997). In contrast, water couch tends to respond most positively to late spring or summer floods. Both of these species also show a strong ability to recolonise areas where lippia has invaded following regular periods of inundation, as occurred from 1996–1998 when three major flood peaks occurred over three years. They most likely accomplish this through their growth form with below-ground rhizomes. Less common herbaceous species such as

swamp buttercup (*Ranunculus undosus*) and water primrose (*Ludwigia peploides*) possess stolons and these species will die without water (Rea, 1994). Their ability to return after flooding is dependent upon stolon fragments remaining or recruitment from the seed bank, although as the length of time between floods increases, the viability of both vegetative propagules and seed banks declines. (Rea, 1994) also suggested that the longer an area remains dry, the more likely it will respond to flooding with fewer species, reduced vigour and gaps into which weeds can invade. In addition, the longer the dry period persists, the more important but less reliable the seed bank becomes in the revegetation process.

Depth of inundation is also an important factor in influencing the dominance of invasive species or native species. McCosker (1998) examined the depth tolerances of lippia, and concluded that when inundation is less than 20 cm, lippia can grow to the water surface and continue to successfully photosynthesise. However, at water depths of around 30 cm, lippia could not reach the surface and was subsequently covered in algal growth which limited photosynthesis and resulted in plant deaths. This appeared to provide an opportunity for water couch to recolonise areas where lippia had previously been the dominant species.

Another notable aquatic weed in the Lower Gwydir wetlands is water hyacinth (*Eichornia crassipes*). This species thrives in warm shallow waters and has progressively spread westward over time, particularly through dispersal by flows along the Gingham Watercourse. While regular and deeper inundation favours native species over lippia, these same conditions can lead to a proliferation of water hyacinth which requires considerable effort and expense to control. The general trend of reduced flows to the wetlands in recent decades has resulted in large areas drying down which can act to reduce the spread of water hyacinth.

The floristic structure and vegetation community structure is closely linked with the water regime (McCosker & Duggin, 1993). Wetland plants have evolved under a highly variable water regime. This provides variation in the environmental conditions that individuals of various species become established in, and greatly influences the chances of successful establishment. The result of this variability is a patchy and heterogeneous distribution of wetland vegetation (Rea, 1994). Species diversity, habitat complexity and genetic diversity depend upon this variability in flow regime.

Impacts of grazing. Periods of inundation of the landscape following flooding result in a nutrient pulse being released which promotes vigorous plant growth. This surge in pasture productivity is a bonus for grazing enterprises. Therefore, the impact of the reduced flows into the Lower Gwydir wetlands has been a reduction in the carrying capacity of the wetland pastures. Grazing has taken place on the Lower Gwydir floodplains since the mid 1800s. While many enterprises initially grazed sheep, there has since been a progressive switch to grazing cattle. The presence of hard-hoofed herbivores has had impacts on wetland plant communities (Keyte, 1994). Reduced water levels in wetland areas have allowed cattle to graze deep into the heart of many wetlands (Rea, 1994). The impact of cattle grazing on wetland plant species is not yet well understood.

On the “low floodplain”, the structure of lignum communities has become degraded in many areas, with grazing and trampling by sheep and cattle, particularly during dry periods believed to be the cause (Keyte, 1994). Intensive grazing is also believed to be responsible for an observed shift away from perennial pasture species towards annual exotics such as burr medic (*Medicago polymorpha*) and barley grass (*Hordeum leporinum*) (Keyte, 1994; McCosker & Duggin, 1992). Evidence from elsewhere in the Murray-Darling Basin of the impact of cattle on wetland vegetation includes:

- compaction of wet soils leading to lower water infiltration rates, reduced soil water storage, inhibition of root penetration and slowing in seedling establishment;
- changes in nutrient distribution in ecosystems where stock graze in wet areas and return to dry areas to rest with nutrients being deposited in these dry areas in their excreta; and
- removal of biomass from wetlands which can influence wetland based food chains. For example, midges are a major food supply for waterbirds after flooding, and are detritivores. Their populations rapidly increase as a response to the breakdown of plant detritus once wetlands are re-flooded. Reduced biomass may limit midge population growth and reduce an important food source for water birds (Bacon *et al.*, 1992 in Keyte, 1994).

Grazing damages plant tissue, and the plant responds by producing new shoots from meristematic tissue. If grazing pressure is intense and the rate of shoot recruitment exceeds the rate of meristem production, then this 'bud-bank' can be depleted gradually over time. Grazing and a lack of water, may act together to drain the plant of resources and reduce its ability to compete with other species in its environment (Rea, 1994).

The dynamics of the vegetation communities in the Lower Gwydir wetlands have been significantly affected as a result of river regulation which has altered the conditions under which the native plant communities have evolved. The reduced water regime has actually favoured the exotic species lippia and also seen an increase in the occurrence in many terrestrial weed species in areas once considered to be semi-permanent wetlands. The particular impacts of grazing on wetland plant communities have not been quantified and are not well understood at present. Based on evidence from elsewhere in the Murray-Darling Basin it may be a case that river regulation is increasing the impacts of grazing on sensitive wetland plant communities. These questions are yet to be thoroughly investigated.

2.5 Zooplankton and microinvertebrates

There is only minimal published information available on the zooplankton or microinvertebrate communities of the Lower Gwydir floodplain. However, there is some general information available on zooplankton communities from the Murray-Darling Basin, and on microinvertebrate communities in dryland river systems comparable to the Gwydir River.

Murray River zooplankton is often dominated by endemic microcrustaceans originating from upstream reservoirs, whereas Darling River waters comprise mainly rotifers (Shiel *et al.*, 1982). A total of 133 zooplankton species was identified in the lower Murray River (SA) and mean zooplankton density was 199 individuals per litre (Shiel *et al.*, 1982). Similar numbers of zooplankton species were observed in a NSW coastal river (116 taxa), although zooplankton density was much higher (~1000 individuals per litre; Kobayashi *et al.*, 1998). A certain density of zooplankton is required for successful rearing of fish larvae (King, 2004).

Emergence of zooplankton from Gwydir floodplain sediment samples yielded similar abundances (~100,000 individuals per sample) and species richness (~8 species) as compared to samples collected from other wetland sites in the Murray-Darling Basin (e.g. Macquarie Marshes) (Brock *et al.*, 2005). A total of 29 plankton taxa were identified from Gwydir Wetland sediment samples as compared to 26 from the Macquarie Marshes and 29

from the Narran Lakes (Nielsen *et al.*, 2007). The emerging zooplankton community in Gwydir Wetland sediment samples was dominated by rotifer species and chydorids (Nielsen *et al.*, 2007).

2.6 Macroinvertebrates

Reported knowledge of the macroinvertebrate fauna of the Gwydir catchment is sparse, apart from a student report (Bennett, 1996) and an inventory compiled by NSW DECCW (Neal Foster, pers. communication). Bennett (1996) found 87 macroinvertebrate taxa in multiple sites located throughout the Gwydir catchment, from headwaters down to about Moree and, additionally, in the Horton River (Table 2.2). Floodplains and wetlands were not sampled as the study concentrated on riffle habitats. Coleoptera was the most diverse group in terms of species numbers, and Hemiptera in terms of families. However, Chironomidae were not identified to species level and so this group is likely to have been more diverse than estimated. Several groups were represented by only a single taxon, and Plecoptera were represented by a single specimen only. Some taxa were common and widespread throughout the catchment (Ephemeroptera, Hemiptera, Tricoptera and Chironomidae taxa) (Bennett, 1996). No strong differentiation in macroinvertebrate communities was evident between upstream and downstream sites, i.e. invertebrate taxa spread evenly over the catchment, although this could simply have reflected the fact that sampling was restricted to riffle habitats.

Monitoring of macroinvertebrates in the Gwydir catchment undertaken by NSW DNR (Neal Foster, pers. communication) yielded a much higher species count (in excess of 500 species) than the previous study. However, the DNR program ran over several years and all taxa were identified to species level, which probably explains the discrepancy in species numbers recorded.

2.7 Fish, amphibians and aquatic reptiles

Fish. A total of 26 fish species occur, or potentially may occur, in the Gwydir catchment (Table 2.3) (Siebentritt, 1999). Three of these species are rare or vulnerable and six are exotic species. Exotic salmonids (brown trout, *Salmo trutta*, and rainbow trout, *Oncorhynchus mykiss*) are absent from the Lower Gwydir River due to temperature and oxygen requirements. River blackfish (*Gadopsis marmoratus*) and mountain galaxias (*Galaxias olidus*) are similarly restricted to the upland sections of the catchment due to their temperature and habitat requirements. Furthermore, a large portion of this potential fish fauna was not sampled during the NSW rivers survey, and Siebentritt (1999) concluded that the basic fish community in the Gwydir wetlands more likely comprises only nine taxa (Table 2.3).

Two fish surveys undertaken in four sites of the Gwydir catchment (Gwydir River at Yarraman, the Gwydir River at Bingara, Horton River at Upper Horton and Mehi River at Moree) recorded 12 species in the 1983 survey (Llewellyn, 1983) and 14 species in the 1996 NSW rivers survey, respectively (Harris & Gehrke, 1997) (Table 2.4). A report by the NSW Department of Infrastructure, Planning and Natural Resources mentions the occurrence of 14

Table 2.2. Taxonomic composition of the Gwydir catchment macroinvertebrate community (from Bennett 1996).

Taxonomic group	Number of families	Number of taxa
Hemiptera	9	13
Coleoptera	8	21
Diptera	8	12
Odonata	6	11
Trichoptera	5	13
Decapoda	3	3
Ephemeroptera	3	5
Oligochaeta	3	3
Gastropoda	1	1
Bivalvia	1	1
Hirudinea	1	1
Isopoda	1	1
Megaloptera	1	1
Plecoptera	1	1

native species in the Gingham Watercourse, although only some of the species were mentioned, and no references were provided (Caddy, 2005; NSW DIPNR, 2005). The abundances of fish found in the Mehi River site during the NSW rivers survey are presented in Table 2.4, which may represent the typical fish community composition to be expected in Lower Gwydir channels (Siebenritt, 1999). The abundance values suggest that crimson-spotted rainbowfish (*Melanotaenia fluviatilis*) and bony bream (*Nematalosa erebi*) may be the most common native fishes in the system. Further summaries of DPI fish sampling programs for a variety of programs (e.g. NSW Rivers survey, Sustainable Rivers Audit, Integrated Monitoring of Environmental Flows) are presented in a review compiled by New South Wales DECC (Spencer, 2007). Again, in all sampling occasions between 1975 and 2005, two to eleven fish species were recorded in Lower Gwydir sampling sites. Exotic species (common carp, *Cyprinus carpio*; goldfish, *Carassius auratus*; and mosquitofish, *Gambusia holbrooki*) and the native bony bream, carp gudgeon (*Hypseleotris* spp.), spangled perch (*Leiopotherapon unicolor*), and crimson-spotted rainbowfish were most frequently encountered.

It is interesting to note the absence of carp and redfin perch from the earlier survey. Anecdotal information suggests that exotic species have increased their range and abundances in the Lower Gwydir floodplain while native species such as Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*) and eel-tailed catfish (*Tandanus tandanus*) have declined, as suggested by landholders (Siebenritt, 1999). The increase in carp in Lower Gwydir channels is expected to impact on native fish (McCosker *et al.*, 1999), although multiple other factors are likely to have contributed to the demise of native fish in this area and the Murray-Darling Basin in general (Harris & Gehrke, 1997). Carp are thought to have invaded the Gwydir system during major floods in the early 1970s

Table 2.3. List of fish species recorded or distributed within the Gwydir River catchment. V = vulnerable, R = rare, EX = exotic species. Species suspected of occurring in the Lower Gwydir streams are indicated with an *. Source: (Siebentritt, 1999).

Common name	Scientific name	Common name	Scientific name
olive perchlet	<i>Ambassis afaassizii</i>	Lake's carp gudgeon	<i>Hypseleotris</i> sp.5*
silver perch	<i>Bidyanus bidyanus</i> (V)*	spangled perch	<i>Leiopotherapon unicolor</i> *
Goldfish	<i>Carrasius auratus</i> (EX)*	Murray cod	<i>Maccullochella peelii</i> *
common carp	<i>Cyprinus carpio</i> (EX)*	golden perch	<i>Macquaria ambigua</i> *
Darling River hardyhead	<i>Craterocephalus amniculus</i> (R)	crimson spotted rainbowfish	<i>Melanotaenia fluviatilis</i> *
un-specked hardyhead	<i>Craterocephalus stercusmuscarum fulvus</i> *	bony bream	<i>Nematalosa erebi</i> *
river blackfish	<i>Gadopsis marmoratus</i>	rainbow trout	<i>Oncorhynchus mykiss</i> (EX)
mountain galaxias	<i>Galaxias olidus</i>	redfin perch	<i>Perca fluviatilis</i> (EX)
Murray jollytail	<i>Galaxias rostratus</i>	flathead gudgeon	<i>Philypnodon grandiceps</i>
mosquito fish	<i>Gambusia holbrooki</i> (EX)*	Australian smelt	<i>Retropinna semoni</i> *
western carp gudgeon	<i>Hypseleotris klunzingeri</i> *	brown trout	<i>Salmo trutta</i> (EX)
Midgley's carp gudgeon	<i>Hypseleotris</i> sp.4*	freshwater catfish	<i>Tandanus tandanus</i> *
chequered rainbowfish	<i>Nematocentris maculata</i>	lesser salmon catfish	<i>Hexanematichthys leptasis</i>

(Copeland *et al.*, 2003) and there has been a general decline in native fish populations over the last 30 years (Mallen-Cooper, 2000).

Of the native fish species occurring in the Gwydir floodplain, only four were recently detected in pool refuge habitats of the floodplain. Exotic species now dominate the floodplain habitats, especially carp and mosquitofish (Mallen-Cooper, 2000). However, most of the fish species still occur in the middle Gwydir catchment, so there is hope for reestablishment once habitat is restored (i.e. restoration of fish passage and flow regime) (Harris & Gehrke, 1997; Mallen-Cooper, 2000).

The overall change in riverine ecosystems (e.g. altered hydrology patterns and habitat degradation) seem to benefit invasive species, especially carp, while native fish are thought to be more dependent on natural flood cycles for their recruitment (Driver *et al.*, 2005; Gehrke & Harris, 2001; Harris & Gehrke, 1997). The majority of native fish species in the Lower Gwydir spawn during the spring and summer season, with rises in water temperature and or water levels associated with floods being identified as important spawning triggers (Lintermans, 2007; McCosker *et al.*, 1999). Currently, flow rises in summer due to irrigation releases from Copeton Dam are considered inferior as a spawning stimulus for native fish due to the low temperature of releases from the dam's hypolimnion (Preece & Jones, 2002).

Fish barriers and passage. By 2002, there was a total of 84 weirs or barriers accounted for in the NSW Fisheries weir review (NSW Fisheries and NSW DLWC, 2002) of the Gwydir catchment, none of which had fishways. Weirs can have a significant impact on riverine ecosystems, for they alter hydraulic conditions, impact on water quality, and impede fish

Table 2.4. Fish species recorded in the Gwydir catchment during surveys of 1983 and 1996 (table modified from (Harris & Gehrke, 1997). EX = exotic species.

Species	1983 survey	1996 survey	1996 Mehi only
<i>Bidyanus bidyanus</i>	-	1	
<i>Carassius auratus</i> (EX)	1	1	14
<i>Cyprinus carpio</i> (EX)	-	1	46
<i>Gadopsis marmoratus</i>	1	1	
<i>Galaxias olidus</i>	1	-	
<i>Gambusia holbrooki</i> (EX)	1	1	
<i>Hypseleotris</i> sp.	1	1	71
<i>Leiopotherapon unicolor</i>	1	1	2
<i>Maccullochella peelii</i>	1	1	5
<i>Macquaria ambigua</i>	1	1	2
<i>Melanotaenia fluviatilis</i>	1	1	105
<i>Nematalosa erebi</i>	1	1	286
<i>Perca fluviatilis</i> (EX)	-	1	
<i>Retropinna semoni</i>	1	1	8
<i>Tandanus tandanus</i>	1	1	
Total	12	14	9
No exotic sp.	2	4	2

migration (Gehrke & Harris, 2001; NSW Fisheries and NSW DLWC, 2002). Furthermore, the changes induced by in-stream barriers seem to favour introduced species like carp and, therefore, have a significant impact on fish community composition (Gehrke & Harris, 2001; Harris & Gherke, 1997). Barriers affect native fish in multiple ways by disrupting life cycles and migratory behaviour, alter population genetics and create environmental conditions unfavourable to them (Gehrke & Harris, 2001; MDBC, 2003; NSW Fisheries and NSW DLWC, 2002). Most native fish undertake migration, often over considerable distance, during various life stages and, therefore, free passage between habitats is required for them to complete their life history (Lintermans, 2007; MDBC, 2003; NSW Fisheries and NSW Department of Land and Water Conservation, 2002). Fishways can aid fish past artificial barriers if constructed properly and aimed at the specific target species. Unfortunately, many of the fishways constructed in the Murray-Darling Basin were designed for Northern Hemisphere salmonids and function less effectively for native fishes (Mallen-Cooper, 1994). As a result of the weir review in 2002, calls have been made for the construction of suitable fishways or the removal of redundant barriers.

Amphibians. A variety of frog species were reported during the 1998 and 2000–2001 floods (Table 2.5) (McCosker, 1998; McCosker, 2001), and additional information on frog species for 1995 and 1996 was recoded by Courtney (1997; in McCosker 1998). Courtney described a higher frog diversity during the summer flooding of 1995, although no species names were given (McCosker, 1998). Frogs were reported to be very abundant during most breeding

Table 2.5. Presence of frog species during 1995–1996, 1996–1997, 1998 and 2000–2001 flood events compiled from the following documents (Courtney, 1997; McCosker, 1998; McCosker, 2001). Question marks in the table (?) indicate that reports (Courtney, 1997) did not provide specific dates on which frogs were observed.

Species		1995–1996	1996–1997	1998	2000–2001
spotted marsh frog	<i>Limnodynastes tasmaniensis</i>	1 (?)	1(?)	1	1
barking marsh frog	<i>Limnodynastes fletcheri</i>	1 (?)	1 (?)	1	1
salmon striped marsh frog	<i>Limnodynastes salmini</i>	1 (?)	1 (?)		1
beeping froglet	<i>Crinia parinsignifera</i>	1 (?)	1 (?)	1	-
Suddel's frog	<i>Neobatrachus sudelli</i>	1 (?)	1 (?)	1	-
red tree frog	<i>Litoria rubella</i>	1 (?)	1 (?)	1	-
broad-palmed frog	<i>Litoria latopalmata</i>	1 (?)	1 (?)	1	-
Peron's tree frog	<i>Litoria peronii</i>	1 (?)	1 (?)	1	-
quacking frog	<i>Litoria alboguttata</i>	1 (?)	1 (?)		
green tree frog	<i>Litoria caerulea</i>	1 (?)	1 (?)		
rough toadlet	<i>Uperoleia rugosa</i>	1	-		
crucifix frog	<i>Notaden bennetti</i>	1 (?)	1 (?)		
warty water-holding frog	<i>Cyclorama verrucosa</i>	1 (?)	1 (?)		
flat-headed water-holding frog	<i>Cyclorana platycephala</i>	1 (?)	1 (?)		

events, especially the spotted marsh frog. All frog data were produced by analysis of frog calls. Unfortunately, there are no quantitative abundance data for either period besides qualifiers such as whether species were abundant or not. Additionally, there is some uncertainty about the extent of sampling in different years, and the low number of species in 2000-2001 could have resulted from either low sampling effort, a general lack of information in the report (frog information was very sparse, with rarer species not having been included), or simply that frogs were genuinely less abundant that year.

A higher number of frog species was reported by McCosker (1998). However, the main text did not make any reference as to whether these species were absent in later occasions or not, or if their occurrence was simply not reported (McCosker, 1998). Courtney concluded that the Gwydir wetlands were an important frog habitat as several rare or unusual species occurred here (Courtney, 1997). The New South Wales Department of Infrastructure, Planning and Natural Resources noted that the Gingham floodplain was a habitat for frogs, although no species lists or references were provided (NSW DIPNR, 2005b). A report on the Gingham Floodplain management cited the record of 18 amphibians from this area, which is considerably more than the list of species in Table 2.5 (14 species). Again, no species names or references were provided (Caddy, 2005).

Aquatic reptiles. The occurrence of reptile species in the Gingham Watercourse floodplain is noted in a report by the Department of Infrastructure, Planning and Natural Resources, although no species names or references are provided (NSW DIPNR, 2005b). A further

report from the same agency cited the occurrence of 20 reptile species on the Gingham Floodplain, although again no species names or references were presented (Caddy, 2005). Keyte (1994) reported a decline in red-bellied black snakes (*Pseudechis porphyriacus*) in the Lower Gwydir Wetlands (Keyte, 1994). The threatened Murray-Darling carpet snake is also known to occur in Lower Gwydir riparian areas, and at least three turtle species (*Chelodina longicollis*, *C. expansa*, *Emydura macquarii*) are likely to occur in ephemeral and permanent pools and lagoons (Wilson & Swan, 2003). However, no information on flow responses or flooding requirements in these species is available from this catchment.