Chapter 2   Study area and study sites

2.1 Introduction

This study was located in part of the Burdekin Dry Tropics, which is characterized by hot moist summers (November to March) and extended warm dry winters. The magnitude of the summer wet season is highly variable (Fig. 2.1). The study region was bounded by the Haughton River, Barrattas Creeks, the Burdekin River at Gorge Weir and the Bowen River at Collinsville (Fig 2.2). The floodplain has extensive aquifers, especially on the delta, and these have been tapped for nearly a century for irrigation of sugar cane. As demand outstripped supply, recharge of aquifers was achieved by pumping water from the Burdekin River into channels, such as Sheep Station Creek. Subsequently, water has been distributed to upper parts of the floodplain from weirs on the Burdekin River, and more recently by water supplied from the Burdekin Falls Dam. This water resource development has allowed the Burdekin floodplain to become one of the largest sugar producing areas in Australia (84,000ha of irrigated cane – Kerr, 1994; GBRMPA, 2003). The modification of flows, filling of waterways, and other changes to habitats resulting from agricultural activities, have had major effects on fish habitat quality and quantity. Most of the sampling sites were on the floodplain, in the mid to lower reaches of the sub-region. The floodplain comprises a network of levees associated with the main river and distributary channels (ACTFR, 1994), where most of the sites were located.

Figure 2.1 Annual rainfall at Home Hill showing 1967 to present. (South Burdekin Water Board, 2002).

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Figure 2.2 Aerial image of study area showing locations of study sites, including those sites outside of the floodplain proper.

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The Burdekin River is the second largest catchment on the east coast of Australia (130,000 km^2). The presence of a moderate relief in the catchment, accumulation of unconsolidated weathered Tertiary deposits, and the passage over the Burdekin Falls at the edge of the Tertiary erosion surface only 128 km from the river mouth, encourage rapid supply of sediment, creating the largest cuspate delta in Australia (Hopley, 1970). The floodplain is complex and comprises three main components: the estuary, the delta and the rest of the floodplain (ACTFR, 1994). The focus of the agriculture industry has been on the rich loamy soils of the levees.

The first development on the Burdekin floodplain was sheep and cattle grazing. However, the dry tropical climate was ideal for sugar cane production and, in the late 1870's, small sugar plantations began in the Inkerman area. In the 1880's the sugar plantations relied on rain and shallow groundwater tables. The first irrigators used open water lagoons and lakes to irrigate the crops, but the variable magnitude and timing of flooding could not support the expanding needs of the irrigators by surface water alone (Kerr, 1994). The next step was to use the shallow aquifer to irrigate the crops. This worked well until the newly formed water boards found that the water tables were dropping rapidly. The water boards then harvested water (during times of high water) to replenish the ground waters. This was the main form of irrigation until the 1980's. In 1987 the Burdekin Falls Dam was completed which provided a guaranteed supply of water year round. The development and exploitation of water resources in the Burdekin has led to this area producing up to a quarter of Australia's sugar crop (Tait and Perna, 2001). The water boards have been in operation since 1966 (SKM, 1997; SBWB, 2002). Pump rates have been recorded for the past 10 years and are presented for the three years of this study (Fig. 2.3).

Water is released as required from the Burdekin Falls Dam and stored in Clare Weir. From Clare water is pumped into channels, constructed in the late 1980's, to the Burdekin River Irrigation Area (BRIA) which includes the floodplain areas of the Barrattas and Haughton rivers. Water is also released from Clare to sand dams and small weirs, such as the Rocks, where it is pumped out by the North and South Burdekin water boards into either channels (in the south, channels have been constructed which join up to natural creek channels) or distributary streams (in the north, creeks such as Sheep Station, Kalamia and Plantation are used to distribute irrigation water) on the Burdekin Delta. The two water boards operate different systems. The North Burdekin Water Board (NBWB) uses the distributary channels as a pump source and ground water recharge by incorporating drop boards at lagoon outlets, maintaining water levels at higher levels and thereby providing continuous supply into the aquifer. The South Burdekin Water Board (SBWB) still has surface water extraction similar to the NBWB, but water is also pumped into recharge pits to directly replenish the aquifer. In the BRIA water is delivered via channels and stored in balancing storages. Water is pumped directly from the channels. The Water Boards face the problem of falling water tables and salt intrusion, while the BRIA has problems with increasing water tables. Within the Water Board areas most of the irrigation water is directed away from the natural creek systems whereas the BRIA directs tail-water into the main creek (Barratta). Management in both areas affects quality of fish habitat, but somewhat differently, according to the style of management.

Figure. 2.3 Pump rates over last three years for; a) Sheep Station Ck. (Total water pumped at the Rocks for 1999-2003) (NBWB, 1999-2003) and b) Warren's Gully (Total water pumped at Warren's Gully 1999 to 2003) (SBWB, 1999-2003).

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The NBWB operates pumps at The Rocks, Plantation pump 1 and 2, Rita Island and Roncato station. Water is pumped into natural overflow paths into Sheep Station, Kalamia and Plantation creeks. All of these creeks have a series of deep-water lagoons connected by creek channels. The lagoons are used as aquifer recharge and surface water extraction sites. By installing culverts and drop boards at the outlet of the lagoons, water levels are raised to provide sufficient and constant head for aquifer recharge and pumping.

The use of lagoons for storage and recharge has created substantial changes to fish habitat values. The drop-board system, culverts and increased flow velocities all create barriers to fish movement within the system. The increased water levels have waterlogged many of the riparian trees, killing them over time. The introduced para grass (*Brachiaria mutica*) has infested the banks of lagoons and channels, altering habitat structure, and *Eichhornia crassipes* has benefited greatly from the maintained water levels and nutrient loads provided by the irrigation water. Para grass has also been found to decrease channel width and increase instream flows, thus contributing to migration barriers (Bunn *et al*., 1997; Pusey and Arthington, 2003;). The modification of these creeks has therefore created a complex interaction of habitat loss, degradation and weed infestation, affecting fish habitat quality.

The SBWB uses artificial aquifer recharge via large sand pits, with water being extracted from pump stations at Warren Gully, McDowell's pump station and on a series of sand dams. The effects on natural creeks have not been as marked as in the NBWB because the water is run through channels and artificial recharge pits separate from the creeks. Weed infestation is still a major problem, but not as much riparian loss occurs as the water levels have not been increased. Sediment loads may not be as high as they are monitored to avoid pumping heavy loads into the recharge pits and clogging the sands.

Within the BRIA all supply channels have been especially constructed. Water is pumped from Clare Weir into a series of channels and balancing storages throughout the Barratta and Haughton sections of the floodplain. Water is pumped from these channels on to the cane and excess water drains into the Barratta Creeks. Some farms have recycle pits but at present much of the tailwater still reaches the natural watercourses. This has altered the flow regime of Barratta Ck, which was originally a seasonal system and now has perennial flow. During the establishment of the BRIA, riparian corridors and buffers were set aside for habitat conservation (ACTFR, 1994). Riparian habitats on the Barrattas and the Haughton are mostly intact. Two weirs on the Haughton River have altered its flow and habitat values.

2.2 Major influences on fish habitat in the Burdekin floodplain

Historically the Burdekin was dominated by tall open woodland and grassland (ACTFR, 1994). Riparian forests and wetlands were also a dominant feature. Presently the Burdekin floodplain has a total of 84,000 ha of irrigated cane land, 46,850 in the BRIA and 37,200 in the water board areas (GBRMPA, 2003). The high number of sunny days combined with the irrigation scheme allows the Burdekin to produce 10-20% greater per hectare yield than any other region in Australia (GBRMPA, 2003). The remaining developed lands in the floodplain are either grazed, under horticulture or urban.

As indicated above, major factors affecting fish habitat on the Burdekin floodplain are:

- Weirs and dams, drop boards and bund walls create physical barriers to fish movement, greatly reducing connectivity within the sub-catchments and reducing recruitment and dispersal pathways (Plate 2.1 a and b). Drop boards are installed into culverts at outlet points in the lagoons. The drop can be over one metre, allowing no passage of fish. Drop boards can also create a wash out below the structure which itself is a barrier even when drop boards are removed.
- Increased flow velocities through culverts and perennial flow may act as barriers to fish movement. During the drier months, pump rates are highest and therefore so are velocities (Fig. 2.3). Without base flow periods, water velocities through culverts are maintained at levels exceeding the swim rates of most native fish (Hogan, 1994; Harris, 1995; Cotterell, 1998).
- Weed species such as para grass, *E. crassipes* and olive hymenachne (*Hymenachne amplexicaulis*), and native species such as bulrush (*Typha orientalis)*, hornwort or duck weed (*Ceratophyllum demersum*) and rice grass (*Leersia hexandra*), have proliferated as a result of the perennial nature of the irrigation area. Increased nutrient loads have exacerbated the problem (Gutierrez *et al.*, 2000). These weeds may create both physical and chemical (hypoxia) barriers to fish movement (Plate 2.1 c). Floating weed mats block the interface between the water and air and shade out submerged macrophytes such that there is no input of oxygen to the water (Julien *et al.*, 2001), thus creating a barrier of hypoxia. The weed mats are so thick that only the largest flood events (when the Burdekin breaks its banks) can remove them (A. Darwen pers. com.). This poses its own problems in relation to flood heights and damage to infrastructure.
- Loss of riparian trees through water logging and poor riparian management, removing the important links between riparian vegetation and fish diversity (Pusey and Arthington, 2003), such as: regulation of solar energy into the aquatic ecosystem, influencing oxygen production; regulation of rates of thermal transfer, potentially disrupting fish reproduction; input of coarse woody debris which provides important habitat complexity; and input of terrestrial matter (insects and fruit) that are directly consumed by fish.

Plate 2.1 Fish passage barriers

a) Culvert drop board system on Sheep Station Ck.

b) Bund walls on the saltwater interface of Sheep Station Ck.

c) Weeded channels that create physical and chemical barriers to fish migration.

a)

b)

c)

2.3 Sampling sites

A total of 25 sites were sampled to characterize the fish habitat of the floodplain waterways, and to investigate the impacts of habitat changes on fish diversity. To examine the present condition of fish habitats within the Water Board areas, sites were selected in both the North and South Burdekin water board areas (five sites in each, including two low-impact sites).

The sites in the NBWB area were all on Sheep Station Ck (Fig. 2.4). The four impacted sites were selected on the basis of their use for irrigation storage and aquifer recharge. Mostly the sites had a high level of weed infestation and highly disturbed riparian buffer. The low-impact site in the north was a lagoon just off the distributary system and was selected on the bases of low weed infestation and lack of direct flow of irrigation water. In the SBWB area the sites were located on Warren’s Gully and Saltwater Ck (Fig. 2.5). The four impacted sites all received irrigation water and had varying degrees of weed infestation. The low-impact site was not directly connected to the distribution system and had low weed infestation.

Fifteen further sites (Fig. 2.2) were selected to represent remnant values as a benchmark with which to compare the main treatment sites. These sites were only surveyed once. Two of these sites were within water board areas: Lilliesmere was sampled to compare present fish communities to that found by MacLeay in 1883; Hutchings Lagoon was sampled because it has never been overgrown with weeds (it is managed by the local water ski club), and because it has some connectivity to the saltwater reaches at flood times.

2.3.1 Methods for site-specific habitat evaluation

Sites were characterized by: 1) descriptions of physical features, namely aspect (for photo-period), topography, length, width, soil type, bank gradient, flow, land use, substrate and, where available, minimum, maximum and average percent saturation of oxygen; 2) riparian habitat quality, namely width of buffer, continuity, maximum percent shading, by riparian vegetation, of water body, average height of trees, dominant community type and condition of riparian vegetation – condition was given a rating of 1 (highly degraded) to 3 (remnant or intact); and 3) instream habitat quality, gauged by total cover of submerged and emergent vegetation, the dominant plant community and depth, using a similar scoring system. Site descriptions are summarized below.

Figure 2.4 Aerial image showing location of main study sites on Sheep Station Ck.

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Figure 2.5 Aerial image showing location of main study sites on Warren's Gully/Saltwater Ck.

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2.4 The ten main study sites

2.4.1 Sheep Station Creek NBWB

Sheep Station Creek is the largest of the distributary streams in the NBWB area. This is the only creek that drains into Bowling Green Bay; the others, including the Burdekin, drain into Upstart Bay. A common characteristic of the lagoons in this system is that they have a north-south aspect. The east bank is usually of lower gradient and the first point of overflow in flooding. The east bank of this creek drains back towards the Burdekin River. On the west side of the creek (the high levee bank), flows that top the bank enter the Barratta system. During peak floods, water from the Burdekin flows strait across to the Haughton system incorporating all the floodplain levee distributary streams.

The NBWB uses the natural flow path of Sheep Station Ck (created by overflow events and the historical meander of the Burdekin River) to distribute irrigation water. Sheep Station Ck flows are now controlled during base flow by pumping from the Burdekin River (NBWB, 2000). Sheep Station was previously a seasonal stream that would dry out to a series of isolated deep water lagoons. During the driest years even these deep water lagoons were prone to drying out (M. Kelly pers. com.). The sites selected for this project were deep water lagoons on the creek.

Payard's Lagoon

Payard's Lagoon is the second large deep water lagoon downstream of the pump station on Sheep Station Ck (Fig. 2.4). This lagoon was fully covered by weeds at the beginning of the project and was cleaned out in August 2000 (Plate 2.2a). No data was collected on habitat before weeds were removed so data here show estimates (Table 2.1). The effects of weed removal are discussed in Chapter 5. Payard's Lagoon is a large lagoon with a length of 1140 m, 80 m wide and a maximum depth of 4 m. The lagoon has a north-south aspect. The western bank has a steep gradient and is up to 5 m high. The eastern bank has a smaller gradient and would be the overflow pathway in times of flood. The lagoon has cane up to the riparian zone on the eastern side, and in the inlet mangoes have been planted along the bank. The western bank has remnant riparian vegetation with goats and cattle grazing the top end; a road runs between the cane and bank. Table 2.1 show the habitat condition and community structure of the riparian and instream habitats. Silts dominate the substrate.

Dick's Bank Lagoon

Dick's Bank Lagoon is approximately 2 km downstream of Payard's. This is one of the largest lagoons on Sheep Station Ck (Fig. 2.4, Plate 2.2b). The lagoon is 1450 m long by 140 m wide with a maximum depth of 5 m. This lagoon also has a north-south aspect where the west bank is the steep high bank and the east bank is the overflow at the outlet. The lagoon is mostly incised deeply in the banks except at the downstream end where floods would overflow to the east (towards the Burdekin). Silts dominate the substrate. This lagoon is also fully surrounded by sugar cane. There is a small patch of remnant riparian habitat at the upstream end on an island between the main inlet channel and the overflow inlet channel. Aside from this patch, most of the lagoon has been cleared and cane grown to the banks. The west bank has a road and houses along it. In early 2001, however, money was given to the EPA to establish revegetation sites along Sheep Station Ck and Dick's Bank was the first site for the project, so habitat is being restored, but was not considered in the collection of data for this project. Riparian and instream habitat and condition and presented in Table 2.1. Of major significance to this site is a direct link to Castelanelli's Lagoon, which has very high habitat and remnant values which contributed to fish assemblage recovery in this site (Fig. 2.6 and Chapter 4).

Kelly's Lagoon

Kelly's Lagoon is "low impact" lagoon for Sheep Station Ck (Fig. 2.4, Plate 2.2c). It was selected as it is within the catchment but is off the distribution system of the NBWB, only receiving back water which maintains the water level. There is only one landholder on the lagoon and he has made efforts over the years to keep out weed infestations (winning the 2002 Landcare award). The lagoon is between Payard's and Dick's Bank and just west of the Sheep Station main channel. At times of flood, water flows through Kelly's from an overflow on Sheep Station Ck Kelly's is a small wash-out lagoon in an overflow pathway. The lagoon is 700 m long by 80 m wide with a maximum depth of 3.5 m. The lagoon has a north-south aspect where the east bank is high gradient and the west bank is low gradient and would overflow at moderate to high floods. Silts dominate the substrate. The channel downstream has been leveled and is now cane land. The lagoon is used for grazing and has a house on the east bank, therefore no cane is planted in the riparian areas of the lagoon. Unlike the other lagoons in Sheep Station Ck the water in this lagoon clears quickly after flood events and has the characteristic "black water". Riparian and instream habitat and condition are presented in Table 2.1.

Gorizia's Lagoon

This site is 4 km downstream of Dick's Bank (Fig. 2.4, Plate 2.2d). The site is one of the most heavily degraded with no open water except at the inlet. However, this lagoon has also been cleaned out since the beginning of the project (August 2002). As with Payard's only the pre-clearing data will be presented. This site also has the least riparian vegetation. The lagoon has an aspect of north-south. It is a large lagoon being 1400 m long by 300 m wide. The substrate is dominated by silt. The east bank has a very low gradient and due to high water levels maintained by irrigation water, the width of the lagoon is exaggerated and there is an area of shallow water (50 cm or less) on this bank that is 100 m wide. Due to this low flooded area the cane is planted about 300 m from the lagoon on the east bank. The west bank is a steep gradient about 3 m high, mostly vegetated bymango trees and some paper bark revegetation. The site is surrounded by cane fields and has two houses on the west bank with a road between the cane and lagoon on this bank. The maximum depth is 3 m, however most of the lagoon is 2 m or less. The weed mat was so developed that people could walk over it. Riparian and instream habitat and condition are presented in Table 2.1.

Jack's Lagoon

This site is 1.5 km downstream of Gorizia's (Fig. 2.4, Plate 2.2e). It is the most degraded site, with full weed cover of the lagoon. The fish sample site was a small open water area at the downstream end, 70 m long by 30 m wide with a maximum depth of 1.5 m. The substrate is dominated by silt. The whole of the lagoon is 1000 m long by 50 m wide. At the time of sampling no depth data was taken due to lack of access (weed infestation). The riparian area on the east bank is grazed and comprises mainly introduced grasses. The west bank is steep gradient about 3 m high and contains most of the remnant riparian trees. The east bank has a low sloping gradient with a large shallow area. There is a small patch of *Livistona* palms with sparse trees along this bank. This lagoon has also been cleaned out but no post-clearing data was taken. Riparian and instream habitat and condition are presented in Table 2.1.

2.4.2 Warren's Gully/ Saltwater Creek (SBWB)

Warren's Gully is a natural overflow path from the Burdekin River, but is not as well developed or defined as Sheep Station Ck. This area has a very small catchment and only flows naturally during bank overflow from the Burdekin. The SBWB has modified this overflow pathway by constructing channels that connect the deepwater lagoons.

Table 2.1 Summary data for riparian and instream community and condition in Sheep Station Creek main sites. Names with * indicate exotic plants. Riparian condition is based on rating of 1-3 where 1=highly disturbed, 2=moderately disturbed and 3=remnant. Figures in brackets for Payard's indicate instream cover before weed removal.

Stie	date	Width buffer (m)	Continuity of Riparian (%)	Max shading of water (%)	Avg. height of trees (m)	Dominant Riparian Community	Riparian Condition	Dominant instream community	Depth of macrophyte growth (m)	Instream cover of submerged macrophytes (%)	Instream cover of emergent macrophytes (%)
Dick's Bank	09/08/01	5	10	5	7	*Melaleuca dealbata, N. orientalis, Brachiaria mutica*, Panicum maximum*, Livistona drudei*	1	*Eichhornia crassipes*, B. mutica*, T. orientalis, Nauclea nucifera,*	5	10	70
Gorizia's	08/08/01	4	10	0	7	*L. drudei, M. dealbata, B. mutica*, P. maximum**	1	*Leersia hexandra, Vigna* spp., *T. orientalis, B. mutica*, Cyperus scaber*	5	0	100
Jack's	08/08/01	0	0	0	10	*B. mutica*, M. dealbata, Typha orientalis, L. drudei, Parkinsonia aculeata*	1	*E. crassipes*, B. mutica*, C. scaber*	4	5	95
Kelly's	08/08/01	7	30	5	10	*M. dealbata, Eucalyptus. tessellaris, E. tereticornis, L. drudei*	2	*L. hexandra, B. mutica*, Salvinia molesta*, Nymphaea violacea, Nymphoides indica, Nelumbo nucifera, Ceratophyllum demersum, Hydrilla verticillata, Chara vulgaris*	3	30	25
Payard's	24/07/01	20	60	10	20	*M. dealbata, Msngifera indica*, Albizia procera*	2	*B. mutica*, C. demersum, H. verticillata, E. crassipes*, B. mutica, E. crassipes, T. orientalis, Cyperus* spp. and *L. hexandra*	2 (0)	30 (1)	10 (99)

Plate 2.2 Sheep Station Ck. main sites

a) Payard's Lagoon (August 2000)

b) Dick's bank Lagoon taken from east bank looking downstream (9-August-2001)

c) Kelly's Lagoon taken from south-east end looking upstream (at 8-August-2001).

d) Gorizia's looking downstream while standing on the weed mat (2-August-2001)

e) Jack's Lagoon from west bank looking upstream (8-August-2001)

a

b

c

d

e

Figure 2.6 Aerial image showing connection from Dick's Bank to the high value remnant Castelanelli's Lagoon

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The SBWB has modified this overflow pathway by constructing channels that connect the deepwater lagoons. The channels are maintained using excavators with rakes to clear the weed and grass from banks for more active groundwater recharge. Most of the water pumped by farmers in this area is from off-channel groundwater sites (SBWB, 2000). There are permits to pump from channels, however, and the water board maintains these areas. Due to the constructed nature of Warren's Gully and the higher number of ground water users, keeping the channels clear of weed is a core function of the water board (SBWB, 2000). The lagoons, however, have not received as much maintenance. The water board needs the channels and lagoons to be relatively clean so that water can be pumped through. Also some areas are left with weeds to "filter out" sediments that slow the recharge process by sealing the banks and sand pits used for active recharge (SBWB, 2000). Three sites are located on this system for this study.

Saltwater Ck is a well-defined creek system that drains the black soil country to the southeast of the Water Board area (Fig. 2.5). This is a natural creek system with limited impact from the irrigation works. Some irrigation water at the tail end overflows into Saltwater Creek just upstream of the Bruce Highway, but mostly this creek maintains natural flow patterns. In 2002 flow from Warren's Gully was diverted and the result was an almost complete drying of the Saltwater Ck site. This catchment flows seasonally with the onset of the wet season. There is a minor barrier at the upper tidal limits, which submerges in most flood events.

Fowler's Lagoon

This is the most upstream site and is the first lagoon that occurs on Warren's Gully (Fig. 2.5, Plate 2.3a). The site is a very narrow channel – like lagoon, which would not be perennial without Water Board pumping. This site is shallow with a maximum depth of 2.5 m and a silt substrate. The site is 700 m long by 30 m wide with an east-west aspect. Both the north and south banks are of medium gradient about 2 m high. There is cane to the banks on both sides of the lagoon and flows are typically high with high turbidity. The site has moderate to high impacted habitats. Riparian and instream habitat and condition are presented in Table 2.2.

Princess Lagoon

Princess Lagoon is located 4 km downstream of Fowlers (Fig. 2.5, Plate 2.3b). This site is the most degraded of the sites in the SBWB area. The site is small with a length of 580 m by 50 m wide, although a large channel runs upstream for another 1000 m but was not considered for this study. There was a small open water area located at the downstream end, which was 75 m long by 20 m wide, which is where the fish samples and water quality were taken; the rest of the lagoon is covered by weed. The substrate is silt. The lagoon has an east-west aspect and both the north and south banks are low gradient of 1.5 m high. Cane is planted on both banks. On the north bank at the upstream and downstream areas there is a buffer up to 30 m wide of riparian trees with a guinea grass understory. The flows at this site are much slower and the water is much less turbid than at Fowler's. Riparian and instream habitat and condition are presented in Table 2.2.

Munro's Lagoon

Munro's is a large lagoon 2 km downstream of Princess (Fig. 2.5, Plate 2.3c). This lagoon is 1060 m long by 100 m wide with a maximum depth of 4.5 m. The substrate is dominated by silt and sand. The aspect of the lagoon is east-west with medium to high gradient banks about 2 m high. The irrigation channel enters the lagoon on the north bank in the middle. There is a large infestation of *E. crassipes* and grass (in the upstream section) 50 m upstream of the inlet. Cane is planted on both banks, but the upstream section has a wide shallow area where the channel widens. The cane is planted on the levees and the lower lying area within the channel still has some vegetation. Riparian and instream habitat and condition are presented in Table 2.2.

Inkerman Lagoon

This site was selected as the control site for the SBWB area (Fig. 2.5; Plate 2.3 e and f). This site receives no irrigation water at all and is on Saltwater Ck catchment above where Warren's Gully overflows into the system. The natural hydrology and water quality data indicate strong groundwater relationship (Chapter 3). The lagoon is large, 1500 m long by 130 m wide with a maximum depth of 5.5 m, and is located 200 m to the south of Munro's. The substrate is dominated by silt with some sand, and a rock bar of granite bedrock in the top end. The aspect is east-west and both the banks have a low gradient with a height of 1.5 m. Cane is grown at the upstream end on the north bank and is planted within 20 m of the bank. Horses and, at times, cattle graze the remainder of the lagoon, but the riparian zone is mostly intact and has high species diversity. This lagoon has high remnant habitat quality and instream habitat diversity. Riparian vegetation and instream habitat and condition are presented in Table 2.2.

Saltwater Lagoon

This is the most downstream site, 3 km downstream of Inkerman (Fig. 2.5, Plate 2.3d). Water from Warren's Gully overflows from Washpool Lagoon on Warren's Gully, into Saltwater

Ck 500 m upstream of this site. Water levels are maintained by this overflow; however, the SBWB diverted the overflow in 2002 and the site almost dried out before seasonal rain started to fill it again (B. Lowis, pers. com.). The lagoon is large but shallow, 1000 m long by 50 m wide with a maximum depth of 2 m and a silt/sand substrate with patches of bedrock. The south bank has a medium gradient and is 2 m high, while the north bank is low shallow gradient to 1 m high. The riparian zone on the north bank is State-owned and is a Main Roads easement, with intact buffer. The south bank is grazed and moderately disturbed. Riparian and instream habitat and condition are presented in Table 2.2.

2.5 The fifteen remnant sites

2.5.1 Barratta Creek Catchment

Barratta Creek is the main floodplain drain path of the Burdekin-Haughton floodplain also known as the "left bank" of the Burdekin (Nicholls, 1980; ACTFR, 1994). The area is approximately 900 km^2 and is a gently sloping plain only interrupted by the complex pattern of channel, levees and floodplains created by the underlain fluvial sediments (Nicholls, 1980). Historically this area was dominated by tall open woodland, grassland and dissected by closed riparian vegetation and *Melaleuca* forests (Nicholls, 1980; ACTFR, 1994,). Vegetation is largely determined by soil types which are varyed from cracking clays, duplex soils, uniform and gradational soils on the levees (Hopley, 1970). Presently an area of 46,850 ha is under cane and irrigated via channels from the Burdekin (GBRMPA, 2003). Irrigation water is all delivered via channel systems but a large amount of water is returned to the Barratta Ck as tailwater.

Woodhouse Lagoon

This is the most upstream lagoon on the Barratta Ck (Fig. 2.2, Plate 2.4 a and b). The lagoon is on Woodhouse Station and used for water supply and grazing. The lagoon has a north-south aspect with medium gradient bank to 2 m high. The riparian zone on the east bank has been more disturbed by clearing than the west bank, and there is a cleared area on both banks of the lagoon in the middle due to power line crossing.

Table 2.2 Summary data for riparian and instream community and condition in Warren's Gully main sites. Names with * indicate exotic plants. Riparian condition is based on rating of 1-3 where 1=highly disturbed, 2=moderately disturbed and 3=remnant.

Site	Date	width buffer (m)	Continuity of Riparian	Maximum shading of water	Avg. height of trees	Dominant Riparian Community	Riparian Condition	Dominant instream community	Depth of submerged macrophyte growth (m)	Instream cover of emergent Macrophytes	Instream cover of submerged macrophytes
Fowlers	07/08/01	7	20	5	7	*M. dealbata, B. mutica, P. maximum*	1	*B. mutica, Azolla* spp., *C. demersum, H. verticillata, Chara vulgaris, Utricularia gibba, Potamogeton. crispus*	1.5	60	40
Inkerman	07/08/01	25	60	20	10	*L. drudei, M. dealbata, E. tereticornis*	3	*N. nucifera, C. demersum, U. gibba, B. mutica, Persicaria attenuata*	4	40	30
Munro's	09/08/01	5	30	10	16	*M. leucadendra, E. tereticornis, L. drudei, N. orientalis, B. mutica, T. orientalis*	2	*E. crassipes, B. mutica, S. molesta, C. demersum, N. nucifera*	3	70	20
Princess	07/08/01	12	40	10	8	*M. dealbata, E. tessellaris, B, mutica, P. maximum*	2	*E. crassipes, B. mutica, C. demersum, T. orientalis*	1.5	60	20
Saltwater	08/08/01	15	95	60	10	*E.agallocha, M. leucadendra, L. drudei*	3	*C. demersum, S. molesta, N. violacea, E. crassipes, B. mutica, Hymenachne amplexicaulis*	1.5	70	80

Plate 2.3 Warren's Gully main sites

a) Fowler's Lagoon looking downstream from pump station during low flow (7-August-2001) (NB. All the para grass has been sprayed)

b) Princess Lagoon looking downstream from northern bank (7-August-2001).

c) Munro's Lagoon looking upstream at the inlet channel from the south bank (9-August-2001).

d) Saltwater Lagoon taken from the south bank looking upstream (8-August-2001).

e) Inkerman Lagoon looking upstream from bottom end (7-August-2001). (NB. The lagoon is drying back because there is no artificial top up from irrigation water).

f) Inkerman during the November 2001 floods looking downstream from the boat ramp.

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The substrate is sand and silt. The lagoon receives irrigation water which increases the suspended solids and the water is "dirty". The lagoon has a maximum depth of 4 m and is 1100 m long by 60 m wide. A cane paddock is now being prepared on the east bank, which will increase turbidity from runoff. The lagoon flows into a heavily vegetated channel downstream with up to 80% cover of the water. High groundwater pressure is indicated by a distinct dirty water line at the outlet keeping the turbid water in the lagoon. This site has high priority conservation values as a fish habitat area and fish refuge. Riparian and instream habitat and condition are presented in Table 2.3.

Clay Hole

This site is located on a tributary of the Barratta Ck, Pelican Ck 2 km upstream of Allan Rd. (Fig. 2.2, Plate 2.4c). The lagoon is on leasehold grazing lands with tailwater running into the creek upstream of the site. The lagoon is medium – sized, 800 m long by 40 m wide with a maximum depth of 3 m. The lagoon has a north-south aspect with high gradient banks 2 m high. Due to tailwater the site is perennial. This site has very low cover of submerged macrophytes and the dominant instream habitat is woody debris and leaf beds, with a sand silt substrate. There is still good connectivity through to the Barratta and estuary which shows in the fish surveys. Riparian and instream habitat and condition are presented in Table 2.3.

Allan Rd. to the Fork

This is a lotic site (Fig. 2.2, Plate 2.4d). There were two distinct reach habitats namely, runs and pools. The area sampled was 6000 m long by 30 m wide with a maximum depth of 4 m, but averaging 2 m. The riparian buffer is all leasehold lands set aside by Department of Natural Resources as habitat and wildlife corridors (ACTFR, 1994). The site has very minimal impact aside from receiving tailwaters. There are, however, patches of *Hymenachne* establishing on the banks which may become a riparian pest if not controlled. The substrate is predominantly sand with leaf litter beds, large woody debris and silt in the deeper pools. Riparian and instream habitat and condition are presented in Table 2.3.

West Barratta Creek at Bruce Highway

This is one of the largest sites, running 4000 m by 70 m wide with a maximum depth of 6.5 m, averaging 4.5 m (Fig. 2.2, Plate 2.4 e and f). The substrate is mainly sand with leaf litter, large woody debris and silt. This is a channel lagoon having lentic and lotic characteristics, although it lacks any run or riffle habitat. The aspect is north-south with high gradient banks up to 3 m high.

Plate 2.4 Barratta Ck. sites

a) Woodhouse from the east bank looking downstream on the main lagoon (30-January-2002).

b) Woodhouse clear water channel downstream of the lagoon proper (22-August-2002).

c) Barratta Ck. Allen Rd. Taken from the south bank showing the various types of habitat (30-January-2002). The images were taken midway from Allan Rd. to the Fork.

d) Clay Hole taken from south Bank showing intact riparian and instream snags (22-August-2002).

e) & f) West Barratta from west bank 500m downstream of highway. Images show riparian trees (e) and dominant instream habitats (f) (30-January-2002).

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The east bank is grazed by Jerona station and was declared a Nature Refuge in 2002 (B. Galloway, pers. comm.). The west bank has a buffer averaging 70 m between the cane crop and the water. Tailwater enters the site from upstream as well as the cane farm on the west bank. The instream habitat is dominated by woody debris and emergent bank vegetation. This site is 2 km upstream of the saltwater interface. Riparian and instream habitat and condition are presented in Table 2.3.

Horseshoe Lagoon

This is the only site that is a characteristic shallow floodplain wetland (Fig. 2.2, Plate 2.5a). Horseshoe Lagoon is a large shallow basin, 1500 m long by 500 m wide, with a maximum depth of 3 m, averaging 1.5 m. The substrate is mainly silt with patches of sand. The site is characterised by dense growth of macrophyte beds and has very limited riparian habitat. *Cabomba carolinensis* has been introduced and is taking over as the dominant species. This site now receives tailwater from channels and cane fields upstream. Previously this lagoon would have dried up in most years except for the very deepest section. It is now maintained at bank full most of the year. The lagoon drains almost directly into the Haughton Estuary, so has a very good connection with the saltwater reaches. Riparian and instream habitat and condition are presented in Table 2.3.

2.5.2 Burdekin River sites

The sites selected on the Burdekin River were chosen to represent the habitat of the major fish refuge and recruitment source for the floodplain. Sites were sampled from Rita Island to the junction of the Bowen River, both above and below the Clare Weir. All sites, except Rita Island, were lotic. The riparian habitat is very different due to the large size of the river. Instream habitat was more characteristic of lotic environments with less macrophyte cover and increased sand and woody debris, than the distribution channel sites. Lengths were not measured at the sites due to the continuous nature of the river.

Bowen River Junction

This is the most upstream of all sites selected and is in the upper-most reaches of the defined floodplain (Fig. 2.2, Plate 2.5b). The Bowen River is the southern catchment of the Burdekin River, draining the Eungella Range. This site is 80 km from the river mouth and is well above Clare Weir. The Bowen is the clear-water tributary of the Burdekin, draining granitic ranges. The substrate at the site was sand, granitic bedrock, macrophyte beds and leaf litter beds. There is also a weir at Collinsville upstream of this site. The landuse at the site is cattle grazing and there is no exclusion from the watercourse. Both the banks have a moderate to high gradient with undisturbed upper story riparian zone. The understory is disturbed by cattle. Riparian and instream habitat and condition are presented in Table 2.3.

Clare Weir

This is another river site and is the holding storage above the weir (Fig. 2.2, Plate 2.5 c and d). It is a large area and only the habitat just upstream of the weir was surveyed. The river is 400 m wide at this point and flows in a north-south direction. The depth is up to 5 m with a sand, silt and bedrock substrate. The habit of the site has changed from lotic to a more lentic reservoir. The riparian habitat is intact and the eastern bank is grazed. Cane is planted on the levee of both banks. This is where water from the BFD is stored for release downstream to the water boards and BRIA. Riparian and instream habitat and condition are presented in Table 2.3.

Burdekin Rocks

At this site there is a small weir to lift water for the Sheep Station Ck pump station (Fig. 2.2, Plate 2.5 e and f). The site is 315 m wide. The maximum depth is 3.5 m but averages less than 2 m. The substrate is dominated by sand and granite bedroCk Flows here are moderate to fast due to releases from the Clare Weir. The river flows north-south and the banks both have a high gradient but the east bank is more gradual. The banks were 15 m or more high. Cane is grown on the levees of both sides, although the west bank is highly impacted by clearing with no riparian trees left. Riparian and instream habitat and condition are presented in Table 2.3.

Rita Island

This site was sampled during a fish rescue, and is very different from all the others, but is included here to show the diversity of habitats on the floodplain. The site is located in a braided channel downstream of the bottom sand dams (the Burdekin is saltwater – influenced adjacent to this site). Groundwater flows usually maintain the levels during average rainfall years. The substrate is sand and there are very dense beds of macrophytes with woody debris throughout the lagoon. This was a small water hole, 100 m long by 50 m wide with a maximum depth of 2 m. Riparian and instream habitat and condition are presented in Table 2.3.

2.5.3 Upper Burdekin Floodplain levee lagoons

The sites were all located on the “Left Bank” of the Burdekin on the levee. This area is in the upstream reach of the floodplain. The sites are in overflow channels and the lagoons are

Plate 2.5 Burdekin River sites and Horseshoe Lagoon

a) Horseshoe Lagoon Taken from the north bank looking upstream (30-January-2002).

b) Bowen River looking downstream to the junction with the Burdekin (01-September-2002).

c) Clare Weir looking east from the west bank

d) Clare Weir looking upstream on the west bank (30-January-2002).

e) The Rocks looking upstream on the west bank.

f) The Rocks east bank (30-January-2002).

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washouts created during times of flow. They were sampled for their remnant habitat values to compare the impacts downstream. However, the lagoons have lost connectivity to the saltwater reaches due to the Clare Weir. This area is the most recent expansion of the sugar industry and impacts are recent. Previously most lands were used for grazing.

Glady's Lagoon

This is the largest lagoon sampled (Fig. 2.2, Plate 2.6a). It is 5000 m long by 80 m wide with a maximum depth of 5 m. The sediments are dominated by silt. Tailwater and irrigation water are run through the lagoon, therefore the water is generally turbid. The aspect of the site is north-south and flows into the Barratta system (historically through a series of shallow wetlands but now through a series of channels). Cane is grown on the east bank and the west bank is grazed by the Burdekin Agricultural College. Both banks are medium gradient to 2 m high. Riparian and instream habitat and condition are presented in Table 2.3.

Swan’s Lagoon

This site has some of the most intact habitats, and is managed by the Swan’s Lagoon DPI research station (Fig. 2.2, Plate 2.6 b and c). There are no artificial flows entering the lagoon (as shown in the plates, the lagoon does dry back). The tailwater from the western bank runs back toward the Burdekin. The site is 1500 m long by 120 m wide with a north-south aspect and maximum depth of 3 m. The banks are shallow gradient and 2 m high. The lagoon is part of a small catchment (Expedition Pass Ck), which flows back into the Burdekin. The DPI uses the surrounding land for cattle research and the cattle are allowed access to the lagoon. Riparian and instream habitat and condition are presented in Table 2.3.

2.5.4 South Burdekin Water Board irrigation splash pool

Warren’s Gully

The site is the splash pool for the pump station at the Burdekin River. Sampling was done here to examine the species pool that could recruit to the downstream lagoons after being pumped into the irrigation system from the Burdekin River. This is not a natural site, as water is pumped out of the river into channels constructed by the SBWB. The area sampled was the splash pool channel (150 m long) and a small pool at the top of the irrigation channel (20 m radius). The substrates are sand and gravel. Riparian and instream habitat and condition are presented in Table 2.3.

Table 2.3 Riparian community and condition assessment for all remnant sites sampled throughout floodplain. Names with * indicate exotic plants. Riparian condition is based on rating of 1-3 where 1=highly disturbed, 2=moderately disturbed and 3=remnant.

Stie	date	Width buffer (m)	Continuity of Riparian (%)	Max shading of water (%)	Avg. height of trees (m)	Dominant Riparian Community	Riparian Condition	Dominant instream community	Depth of sumberged macrophyte growth (m)	Instream cover of submerged macrophytes (%)	Instream cover of emergent macrophytes (%)
Clay hole	9/08/01	10	90	70	10	*M. leucadendra, E. tessellaris, L. grandiflorus*	3	*N. violacea, C. demersum, P. attenuata*	2	5	20
W. Barratta	30/01/03	10	100	40	15	*M. leucadendra, N. orientalis, L. drudei*	3	*P.attenuata, S. molesta*, Lomandra, C. demersum*	6	5	10
Allen Rd.	30/01/03	20	100	80	12	*M. leucadendra, L. drudei, Casuarina* spp., *N. orientalis, Pandanus whitei*	3	*Lomandra, P. attenuata, C. demersum, H. amplexicaulis**	3	5	10
Burdekin Rocks	30/01/03	30	90	5	10	Complex vine thicket	2	*H. verticillata, P. attenuata, B. mutica*, P. crispus*	3	10	10
Clare weir	30/01/03	30	90	50	15	Complex vine thicket *(E. tereticornis, M. leucadendra)*	3	*H. amplexicaulis*, P. attenuata, Blyxa* spp., *N. violacea, H. verticillata*	7	2	2
Glady's	30/01/03	7	60	10	15	*E. tessellaris, E. tereticornis, B. mutica*, E. platyphylla, Cryptostegia grandiflora*, M. dealbata*	2	*N. nucifera, C. demersum, B. gibba, B. mutica*, P. attenuata, T. orientalis, Azolla*	4	30	40
Castelanelli's	30/01/03	5	20	5	10	*B. mutica*, M. dealbata, M. leucadendra, E. tereticornis, L. drudei, N. orientalis, Pandanus whitei, Panicum maximum**	2	*B. mutica*, C. demersum, H. verticillata, N. violacea, T. orientalis*	4	30	10
Horseshoe	30/01/03	0	0	0	10	*B. mutica*, H. amplexicaulis*, M. dealbata, L. drudei*	2	*C. carolinensis*, C. demersum, E. crassipes, Cyperus* spp., *T. orientalis, H. verticillata, Blyxa* spp., *P. crispus, H. amplexicaulis*, L. peploides*	3	90	60

Table 2.3 cont.

Woodhouse	30/01/03	10	60	10	10	*M. leucadendra, C. tessellaris, B. mutica*, C. grandiflora*, P. aculeata**	2	*N. violacea, C. demersum, M. mutica, B. mutica*, Ludwigia peploides, Cyperus*|*Fimbristylis* spp.	3	30	60
Rita Island	30/01/03	20	70	50	15	Complex vine thicket, *(M. leucadendra)*	3	*C. demersum, H. verticillata, P. crispus*	3	80	10
Warrens Gully	30/01/03	10	70	70	10	Complex woodland *(Eucalypt and Corymbia dominated)*	3	*P. crispus, C. demersum, Blyxa* spp.	2	30	40
Swans	30/01/03	30	70	20	10	*E. tereticornis, C. tessellaris,* Grazed grass	3	*N. indica, Azolla* spp.*, P. attenuata, Cyperus* spp.,	2	70	40
Hutchings	30/01/03	10	20	10	10	*M. indica*, S. samanea, L. drudei, Panicum maximum*, B. mutica**	2	*H. verticillata, C. demersum, E. crassipes*, B. mutica*, T. orientalis*	4	30	60
Lilliesmere	30/01/03	60	40	5	25	*M. indica*, S. samanea, L. drudei, Panicum maximum*, B. mutica**	1	Not Available	3	40	30
Bowen River Junction	1/09/02	60	60	20	70	*Allocasuarina* spp. and *M. leucadendra*	3	Not Available	3	40	10

2.5.5 Plantation Creek sub-catchment NBWB

Hutchings Lagoon

This site is the local water ski club lagoon and, due to the regular disturbance by speed boats, *E. crassipes* has never covered the lagoon (Fig. 2.2, Plate 2.6d). The lagoon is large, 1500 m long by 120 m wide and has a maximum depth of 4.5 m. There has been extensive bank modification to stabilize the banks from the effects of the water-skiers. Cane is grown on both of the banks of the lagoon. The aspect of the lagoon is north-south with the banks having a high gradient about 3 m high. Irrigation water flows through the lagoon via the Plantation Ck pump station. During flood periods the lagoon can have connectivity with the Plantation Ck estuary. The substrate is dominated by silt. Riparian and instream habitat and condition are presented in Table 2.3.

2.5.6 Kalamia Creek sub-catchment NBWB

Lilliesmere Lagoon

This is a highly degraded site used as cooling and water supply for Kalamia mill. The site was sampled to compare the present fish assemblage with that found by MacLeay in 1883. The lagoon has a north-south aspect with medium gradient banks. Irrigation water from Plantation Ck is pumped through the lagoon by channels. Just before sampling this lagoon the local Shire removed the *E. crassipes* infestation. Sugar cane is planted on both sides and the riparian area is highly degraded, being dominated by guinea grass and para grass. No further data was collected. Riparian and instream habitat and condition are presented in Table 2.3.

2.5.7 Sheep Station Creek sub-catchment remnant site

Castelanelli's Lagoon

This lagoon was sampled because it is believed to be a species refuge and recruitment source for Sheep Station Ck (Fig. 2.2, Plate 2.6e). The lagoon is unique with a substrate predominantly sand and appears to be a groundwater lens so the pressure from the aquifer keeps the turbid irrigation backwater out, therefore the lagoon is a black water lagoon lacking the high turbidity of the distribution channel sites. The local pony club operate on the eastern bank and the landholder has managed any weed outbreaks in the lagoon. The lagoon is 300 m by 180 m long with a maximum depth of 4 m. Cane is grown on the surrounding levee banks and horses graze on the north-eastern bank. The site is located on an overflow pathway to the east of Sheep Station Ck, with a very small catchment area. The site flows directly into

Plate 2.6 Upper floodplain levee lagoon sites, and Hutchings and Castelanelli's Lagoons

a) Glady's Lagoon taken from the west bank looking upstream (30-January-2002).

b). Swan's Lagoon taken during electro-fishing survey (20-August-2002).

c) Swan's Lagoon during habitat survey (30-January-2002).

d) Hutchings Lagoon looking downstream from east bank (30-January-2002).

e) Castelanelli's Lagoon looking to the east bank (30-January-2002).

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Dick's Bank Lagoon just downstream. Riparian and instream habitat and condition are presented in Table 2.3.

2.6 Summary

Habitats were most impacted in the delta Water Board areas, which are also the oldest established cane growing lands of the whole floodplain (ACTFR, 1994; SBWB, 2002). Riparian vegetation loss and supplemental flows were the main impacts. The loss of the riparian trees and thus shading may benefit the establishment of emergent exotic grasses (Bunn, *et al*., 1998), and has instream impacts on food webs, physico-chemical water quality, and survivorship of aquatic animals (Pusey and Arthington, 2003). Also the modified flow conditions appear to be related to *E. crassipes* infestations, as no other areas surveyed had as high biomass of this plant as found in the Water Board areas (Chapter 3). All condition 1 sites were located in the Water Board distribution systems (Fig. 2.7, Table 2.4), these include the sub-catchments of Plantation and Kalamia Cks. There were, however, important high value areas within these distribution systems (Fig. 2.7, Table 2.4). These were remnant sites that receive no irrigation water as they are off-channel lagoon habitats that only connect to the main streams during high water events. These sites may contribute greatly to the biological diversity of this highly fragmented and impacted landscape (Pearson *et al.,* 2003).

The Burdekin River sites all had high levels of intact remnant riparian vegetation and instream habitat complexity (Condition 3) (Table 2.4). The flows, however, are highly modified and instream connectivity is fragmented by a series of weirs. The upper floodplain levee lagoons again had intact remnant habitats but again lack the instream connectivity to the lower reaches, although, this is naturally the case for these lagoons under all but the highest flow conditions. The sites in the Barratta Ck catchment had both remnant habitat, as well as connectivity to the lower reaches.

The Barratta Ck sites have high conservation values (intact remnant habitat and saltwater connection) and should be managed appropriately. There are pressures on this creek from tailwater runoff from cane fields which can increase nutrient and sediment loads downstream (Rayment, 2002). This input may impact on water quality and aid floating weed infestations (at present *E. crassipes* was not recorded in the Barratta Ck (only *Salvinia molesta* which appears to be mostly under control by the introduced weevils, and natural high flows from wet season flooding), however due to irrigation channels in the upper floodplain levee area, this plant may make it into the system during a large flood event or naturally work its way down the distribution channels. These

Figure 2.7 Aerial image showing location of all sites across the floodplain and (distribution by) condition.

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Table 2.4 Summary of all sites by condition, location, flow and *E. crassipes* infestation. Conditions are: 1=highly degraded, 2= moderately degraded, 3= remnant habitat values; Locations are: 1= Sheep Station Ck., 2= Warren's Gully, 3= Barratta Ck., 4= Burdekin River, 5= upper floodplain levee lagoons and 6= Plantation/Kalamia Cks. (NBWB); flows are: 1=supplemental irrigation flows, 2=tailwater, 3=non-modified flows; and *E. crassipes* infestation: 1=full cover, 2=patchy cover not yet consolidated and 3= none present.

Site	Condition	Location	Flow	*E. crassipes* infestation
Dick's Bank	1	1	1	2
Gorizia's	1	1	1	3
Jack's	1	1	1	3
Fowler's	1	2	1	2
Lilliesmere	1	6	1	2
Kelly's	2	1	3	1
Payard's	2	1	1	2
Munro's	2	2	1	2
Princess	2	2	1	1
Burdekin Rocks	2	4	1	3
Glady's	2	5	2	2
Castinalli's	2	1	3	3
Horseshoe	2	3	2	2
Woodhouse	2	3	1	3
Hutchings	2	6	1	2
Inkerman	3	2	3	3
Saltwater	3	2	2	2
Clay hole	3	3	2	3
W. Barratta	3	3	2	2
Allen Rd.	3	3	2	3
Clare weir	3	4	1	3
Rita Island	3	4	3	3
Warren's Gully	3	2	1	3
Swan's	3	5	3	3
Bowen River	3	4	2	3

sites are suggested to have the greatest biological diversity across the floodplain due largely to the high quality habitat.

In general all sites sampled across the floodplain had at least moderate impacts to riparian and instream habitats. As stated most of the impacts were either riparian clearing or modified flows. Development on the floodplain is extensive but examining the distribution of high value remnant sites shows that these sites are likely to provide refuge and a source of recruitment in most floodplain distribution streams. Is so, this then suggests that management and rehabilitation works on the degraded areas will benefit greatly from these refuges.