# Gladstone Area Water Board Environmental Monitoring Program

## Aquatic Ecosystem Monitoring 2002
## Habitat, Biota and Vegetation Assessment

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2004



Central Queensland
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## 1.0 Executive Summary

Biological monitoring including habitat assessment, water quality, macroinvertebrates and fish sampling was undertaken at four sites downstream of the Awoonga Dam on the Boyne River in January and February 2002. Monitoring and assessment of riparian communities was undertaken at thirty-six sites within six reaches at the same location from February 2002 to May 2004. These surveys were initiated primarily to gain quality baseline information on the aquatic ecosystem and add to the existing Environmental Data Collection and Monitoring Programme (EDCM), which commenced in 1998. Specifically, the monitoring identified instream habitat features, water quality and biota (fish and invertebrates) at sites and provided an appreciation of the structure, extent and composition of riparian vegetation communities along the river. Techniques employed allow comparison with previous surveys. This report presents data and summary information from 2002 aquatic ecosystem monitoring and fulfills hypotheses two, five, six and ten of first year sampling requirements for the Boyne River Basin Resource Operations Plan.

Despite evidence of eutrophication from the physico-chemical and nutrient data (several parameters failed to comply with ANZAC guidelines), there was a diverse array of invertebrate and fish species captured across sites and the aquatic habitat rating for all sites was high. Macroinvertebrates were represented by generalist as well as sensitive species (known to be intolerant of poor conditions). Fish communities included both salt and freshwater assemblages with three species common among the sites. These were *Hypseleotris sp.1* (Midgleys carp gudgeon), *Megalops cyprinoids* (oxeye herring or tarpon) and *Mugil Cephalus* (sea mullet), the latter two of which are migratory fish.

Within the six riparian vegetation reaches, which encompassed the Boyne River from the mouth for the bottom of the dam wall, differences existed in community species composition and richness, zonation and length of sites, stem density and canopy cover. These differences were related to changes in land use and geographical features of the river and catchment.

## 2.0 Introduction

The Port Curtis region is situated between the major catchments of the Fitzroy and Kolan River and includes the drainage systems of the Calliope and Boyne Rivers and associated streams. Awoonga High Dam on the Boyne River provides the only major source of water in the Gladstone area with extensive reticulation networks supplying urban and industrial users in the Gladstone and Calliope area and the Callide valley (SKM, 1999).

To advance sustainable development and management of water within the Boyne River basin, Queensland Department of Natural Resources and Mines released a Resource Operations Plan (ROP) in July 2003. Partial requirements of the ROP include water quality and aquatic ecosystem monitoring which will be used to assist in determining the impacts of Awoonga Dam and of environmental releases on the habitat and biota downstream of the dam (NR&M, 2003). Aquatic ecosystem monitoring of the Boyne River was undertaken for Gladstone Area Water Board in 2001 and 2002 by the Centre for Environmental Management (CEM), Central Queesland University to meet the environmental and conservational commitments in the Boards strategic plan, to add to the existing Environmental Data Collection and Monitoring Programme (EDCM) and in anticipation of fulfilling requirements of the Resource Operations Plan. The 2002 ecological data collected by the Centre for Environmental Management was accepted as adequate for the first years sampling requirements for the ROP hypotheses two and ten (Table 1), providing data were appropriately analysed (NR&M 2003). This summary report will report on most data collected in 2002 at four sites, within six reaches, downstream of the Awoonga Dam including:

- broadscale inventory,
- water quality, sediment and nutrients,
- macroinvertebrates,
- fish,
- freshwater riparian vegetation ,
- estuarine riparian vegetation.

Additional data collected in 2002 but not in this report includes:

- turtle survey,
- critical habitat assessment (for turtle and platypus),
- sediment nutrient analysis.

## 3.0 Methodology

Aquatic ecosystem monitoring was undertaken at four sites downstream of the Awoonga Dam on the Boyne River throughout early 2002 (Figure 1). The two upper sites were located at Pikes Crossing (BOYPD1) and Mann's Weir (BOYPD2) and were typically freshwater environments while the two lower sites at Benaraby (BOYED1) and upstream of the Boyne River/South Trees confluence (BOYED2) were estuarine in nature. Mann's Weir is a 2m high artificial sand and gravel structure forming the salt/fresh interface of the Boyne River system and built to wash away during moderate flows. The broadscale inventory was undertaken in August 2001 but is included in this report as it provides baseline habitat assessment data adequate for the first years ROP sampling requirements.

The majority of riparian monitoring was undertaken within six reaches (6 sites within each reach) on the Boyne River from February to July in 2002, except for five sites that were monitored in May 2004 (3_1b, 3_2b, 4_3a and 6_1a and 1b) (Figure 2). Various riparian parameters were monitored (summary of information by reach provided in Figure 2).

## 3.1 Aquatic Habitat Assessment – broad scale inventory

The broad scale inventory of sites involved classifying selected sites using parameters based on State of the Rivers guidelines. These included:

- habitat type,
- dimensions and depth of pools,
- condition of habitat types – degree of vegetation modification and land uses surrounding the reach,
- left and right bank condition – based on instability and susceptibility to erosion,
- bed and bar condition – stability of the bed based on substrate characteristics and channel obstructions,
- left and right riparian width,
- aquatic habitat rating – based on size of the water body, amount of instream debris, macrophytes and other structure.

Major physical features were noted and four sets of photographs taken at each site (left bank, right bank, upstream, downstream). Banks were classified right or left always facing downstream.

## 3.2 Water Quality

*Physico-chemical analysis*

Routine maintenance and inspection of instruments was undertaken and probes were calibrated according to manufacturers instructions prior to use (TPS Pty Ltd. 1994). At each site depth profiles were determined for pH, conductivity, dissolved oxygen and temperature. This included sampling within the surface 10cm and then at one-meter intervals to the bottom. The time of day was recorded to assist in interpreting results and sampling was conducted prior to activities likely to alter water quality..

To assist in assessing health, values were compared to National Water Quality Management Strategy (NWQMS) guidelines (Australian and New Zealand guidelines for fresh and marine water quality) where applicable (ANZECC and ARMCANZ 2000).

*Water nutrient analyses*

Water samples were collected for determination of nutrient and chlorophyll *a* concentrations utilizing standard sampling methods. Appropriate cleaning, sterilization and preparation of containers were undertaken prior to their use in the field (AS 5567.0 1998). Particular care was taken to avoid contamination from acid by using disposable gloves, not touching the sample in any way and using uncontaminated containers. Sampling depth was measured from the surface of the water to the middle of the sampler. Samples were collected from the center of the channel, away from aquatic plants with the container facing the flow of water.

Chlorophyll *a* samples were filtered immediately following collection, with two or three drops of magnesium carbonate suspension added to the filter before filtration to prevent the sample from becoming acidic. A know volume of water was filtered through a Whatman GF/F filter (pore size approx 0.5μm) which was immediately frozen. Chlorophyll samples were kept in the dark or in containers wrapped in foil and were analysed as soon as possible after collection.

One water sample per site was collected, placed into an appropriate container and refrigerated for transport back to the laboratory. Chilled samples were then transported to a NATA accredited laboratory for analysis of ammonia, nitrate, total nitrogen, total phosphorus (filterable), filterable reactive phosphorus (FRP), total suspended solids and chlorophyll *a.*

Notes: Filterable (or dissolved) reactive phosphorus (FRP or DPR) methods are used to estimate amounts of *immediately* and/or *readily*-bioavailable phosphorus (orthophosphate P04) whereas filterable total phosphorus measures *potentially*-bioavailable phosphorus (particulate and dissolved) (Zhang 2001). Some studies caution of overestimation of true orthophosphate concentration by FPR methodology (Robards 1993).

*Quality assurance during sampling*

Accurate field data recording and labeling were undertaken and where measurements appeared suspicious replicate samples were taken. Chain of custody documentation was used for sample transport to the laboratory. Probe calibration and maintenance is particularly important and was at all times follow manufacturers instructions. Technicians at all times observed standard operating procedures including wearing of disposable gloves, decontamination of sampling equipments between locations, use of deionised water and maintaining accurate records.

## 3.3 Macroinvertebrates

*Kick/Sweep netting*

Aquatic macroinvertebrates were sampled using a kick/sweep net (a triangular frame, 35cm along the base and 30cm sides, supporting a bag comprising of 250µm mesh) following AusRivAS protocols (DNR&M 2001). A length of approximately 10m along the creek edge was sampled with substratum being disturbed by feet and hands to dislodge specimens into the net held downstream of the sampling area. The sampling area covered a variety of velocities and different regions of the site. Large rocks were examined and specimens removed.

The sample was then placed into a container with a waterproof label and 5% formalin (higher concentrations were required if sample material was woody). The sweep net was checked prior to and after use for damage and to remove any remaining specimens. The sample container was sealed and inverted several times to ensure adequate mixing.

*Grab sampling*

Benthic macroinvertebrate fauna was sampled using a Van veen grab (diameter 16cm and penetration 8cm) attached to a hydro wire using a swivel to minimize twisting forces and ensure that proper contact was made with the bottom. The grab was lowered at a slow speed entering the sediment at 0.3m/sec and (after hitting the bottom) raised at a slow and constant speed to allow its proper closure and to avoid disturbing the sample. The sample was bought on board or on shore with minimal disturbance and checked to ensure that

- sediment is not extruded from the upper face of the sampler (no sediment lost),
- overlying water is present (suggesting seal is adequate and sample is whole),
- the sediment surface is relatively flat (minimal disturbance to the sample) and
- the following penetration depths are achieved – 4-5cm for mediums to coarse sand, 6-7cm for muddy sand and >10cm for mud.

General observations included notes on site location, depth, texture and colour or sediment, biological structures present, debris, oil or smell present, characteristics of sediment profile and any disturbance while sampling. The sample was then placed in a labeled bucket and

sieved (1mm mesh size) utilising a gentle hose stream to minimize damage to specimens. When sieving was complete the remaining sample was placed into a labeled container with 5% formalin (higher concentrations required only for woody samples) and the sieve checked (any remaining specimens added to the sample) and rinsed. After being sealed the sample container was inverted several times to ensure adequate mixing.

*Laboratory sorting*

Following fixation in formalin for between 24 hours and 7 days (ideally 72 hours), samples were transferred to 70% ethanol with glycerol added for continued pliability. This involved decanting formalin (appropriate sieve mesh either 1mm or 250µm as per collection method) and refilling the sample container with ethanol (with glycerol added). The original waterproof label remained with the sample at all times and the sample container was relabeled appropriately. Samples were cross-referenced against a log sheet at all preservation stages and were stored upright in a chemical storage facility.

Prior to sorting, samples were rinsed through sieves using a low-pressure water stream (appropriate sieve mesh either 1mm or 250µm as per collection method). Samples were sorted using direct sorting and floatation. Direct sorting involved the placement of portions of the sample in a petri dish and, using jewelers' forceps to pick through the sample systematically, removing all the organisms under a dissecting microscope. Floatation involves immersing the sample in water, sieving off floating debris, soft bodied organisms and crustaceans and sorting as above, prior to sorting the remainder of the sample. This was particularly useful when large numbers of crustaceans were present in a sample. One person would sort each sample.

Samples were sorted according to the following version of AusRivAS methodology and were then sorted in the laboratory only to increase repeatability (DNR 2001).

1. large samples were subsampled (minimum of 10% of total sample).
2. the sample was sorted for a minimum of 30 minutes using forceps and pipettes and the total abundance recorded using a handheld counter.
3. only 10 specimens of any one type (family and in some cases order) of animal were collected. All specimens of uncertain identity were collected. At lease 30 midge larvae (Chironomidae) were collected to ensure adequate representation of the sub-families.
4. at the start of sorting, the common and abundant taxa were picked for about the first 5 minutes. After that, the major picking effort was directed at finding the less common, inconspicuous taxa. After 10 minutes no more common taxa were picked unless it was suspected that a particular common form contained more than one family, or it was a common taxon overlooked originally.

Identification was to family level using the keys of Williams (1980) and Dean (1991). Samples were retained for future reference at Central Queensland University.

*Quality Assurance*

Laboratory Sorting

Internal quality assurance and control checks for error rates in sorting were undertaken. Following sorting, sample waste (with site label and sorter history) was placed aside. At least 10% of the sample waste was resorted by an assigned person and the number of animals picked out counted and calculated to 100%. This number was compared to the total count of specimens previously picked from the sample. Error rates greater than 10% (>10% of the total number of animals previously picked from the sample) failed quality assurance and the sample was resorted. Error rates (often dictated by speed and style of sorting) were discussed with the original sorter and noted in the laboratory notebook for the project, which was read

and signed by all members that underwent the QA check. QA was performed on all staff participating in macroinvertebrate sorting.

Identification and numeration

Internal quality assurance and control checks for error rates in macroinvertebrate identification and numeration were undertaken. Previously identified and counted samples were re-identified and re-counted by an assigned person and checked against a verified reference collection. Previously identified samples were stored by site and replicate at family level to facilitate this process. The resultant taxa lists were compared and discrepancies in identification checked by other staff and against reference specimens. Any errors were discussed with the original identifier (both in misidentification and numeration) and both errors and error rates noted in the laboratory notebook for the project, which was read and signed by all members that underwent the QA check. Error rates of more than 10% were not acceptable and any previous samples identified by a person with >10% error in identification or numeration were re identified and counted. For this reason, QA processes must be initiated from the start of the identification phase.

## 3.4 Fish Sampling

Gill nets were deployed at each site in order to target barramundi and mullet species in particular. Two three panel nets (1x 1'2'3' and 1x 4'5'6') were positioned across the water body at different locations at, least 20 meters apart, to enable capture of a range of species and sizes. The nets were set up approximately two hours before and retrieved approximately two hours after dusk and were checked regularly to avoid drowning crocodiles, platypus or turtles.

Eight fish traps baited with dry dog pellets (proven fish attractant) were deployed in shallow areas or areas where complex habitat structure was present to enable capture of juvenile and small species (i.e. rainbow and gudgeon).

Seine netting (for further capture of juvenile or small fish) was conducted at locations where macrophyte cover did not obstruct netting and where riverbanks were accessible. A standard 10m (out from bank) x10m (along bank) area was netted. Two hauls of a seine net were undertaken at each location.

All target fish species caught were identified, counted and measured (other species were) (Grants 1999, Allen *et al* 2002). Fish were released alive where possible, unless further identification was required. Two specimens of each species were retained for verification of identification by Queensland Museum or the Centre for Environmental Management reference collection.

## 3.5 Riparian vegetation assessment

The river was classified into reaches; taking account of the natural architecture of the river, water resource monitoring points and large-scale land use (Figure 2). A description of each reach was developed that produced sufficient information for the state of the reach to be assessed. The description included indices of disturbance and naturalness such as weed invasion, stock influences, erosion etc as well as relatively fine scale monitoring of plant species distribution, riparian community extent, structure and zonation. The level of disturbance was classified as low, moderate or high depending on extent.
Six representative sites were established within each reach (Figure 2). Each site was situated perpendicular to the river (compass readings were taken for river direction and transect direction was 90° up the ridge) with a ten-meter wide front at the low tide mark and a length dictated by the height of the riparian ridge. Projective cover (using a FPC tube) of overstorey (>1.5) and groundstorey (<1.5) vegetation was determined from a transect which began in the

at the low tide mark and ran perpendicular from river to the top of the riparian zone (refer to transect maps Appendix 3). From these transects, environmental zones within the riparian zone were identified. A complete species list was compiled for each site and species richness and relative abundance were determined. Identification was to species level where possible using Stanley and Ross (1989) and local reference collections (CQU and Gladstone Botanical Gardens) and samples were retained for future reference at Central Queensland University. Riparian cover and structural characteristics were also noted and a photo record taken for each site.

## 4.0 Results

### 4.1 Broad scale Inventory

All sites received a high aquatic habitat rating based primarily on size of the water body (Table 2). Complex instream structure (a secondary consideration) varied including macrophytes, large woody debris or undercuts for freshwater sites and mangroves, rocky ledges and substrate for estuarine sites. Erosion on the right bank of BOYPD2 and both banks of BOYED2 (Figures 3a and b) accounted for higher erodibility and instability values at these sites. Site photos are presented in Plates 1-4 (BOYPD1), 2-8 (BOYPD2), 9-12 (BOYED1) and 13-16 (BOYED2). The broadscale inventory is a site classification system and does not require discussion unless compared to previous classifications at these sites.

### 4.2 Water quality

Means of depth profiles were calculated for each site. Depth profiles varied considerable, depending on total depth of the site. Australian and New Zealand guidelines for protection of ecological health of aquatic ecosystems exist for dissolved oxygen and pH (and for changes in conductivity) (ANZECC and ARMCANZ 2000). NWQMS classifications include upland rivers (>150m altitude), lowland rivers (<150m altitude) and estuary and marine. For purposes of comparison the two upper sites (BOYPD1 and BOYPD2) on the Boyne River were classified as lowland river (Boyd *pers com* 2004), and the lower two sites (BOYED1 and BOYED2) were classified as estuary, as they were saline in nature.

Dissolved oxygen concentrations at all sites were well below NWQMS recommendations for lowland rivers of 85-100% saturated (Figure 1). At the time of this study freshwater pools BOYPD1 (mean DO 12%) and BOYPD2 (mean DO 36.6%) contained considerable amounts of aquatic macrophytes and sampling was undertaken in the early afternoon to attempt to avoid low measurements resulting from photosynthesis (dissolved oxygen is lowest at early hours of the morning increasing to a maximum through the day) (DNR&M 2000). Dissolved oxygen concentrations at estuarine sites BOYED1 and BOYED2, where macrophytes were absent, were also low (58% and 68% mean DO respectively). The dissolved oxygen depth profiles did not vary substantially in estuarine sites; however, there was a steep decrease in dissolved oxygen with depth at the freshwater sites.

Conductivity values clearly reflected the nature of the habitat (salt versus fresh). There was a large increase in conductivity values measurements at 3m at BOYPD2.

pH measurements were similar within freshwater sites (6.5 and 6.4) and estuarine sites (7.5 and 7.4). Although pH at estuarine sites was within the range for ecosystem health (7-8.5 - estuaries, 6.5-8.0 - lowland rivers), pH at freshwater sites was either marginal (BOYPD1 – 6.5) or fell short of the trigger health value (BOYPD2 – 6.4) (ANZECC and ARMCANZ 2000).

Temperature ranged from 27.7$^0$C (BOYPD1) to 30.2°C and varied minimally between sites.

*Water nutrient analysis*

Analyses of water nutrient levels at the four sites on the Boyne River are presented in Table 4. Australian New Zealand Guidelines for protection of ecological health of aquatic ecosystems provide recommended levels for Total N, Total P and chlorophyll *a*.

Concentration of total N at freshwater sites (0.6mg/L and 0.5mg/L at BOYPD1 and BOYPD2 consecutively) either exceeded or bordered on recommended guidelines for this type of water body (lowland river – 0.5mg/L) whereas total N in estuary sites was smaller (0.2mg/L at both sites) and fell within the recommended guidelines (esturary – 0.3, lowland river – 0.5mg/L).

Conversely total Phosphorus concentration at freshwater sites (0.04 and 0.02 at BOYPD1 and BOYPD2) was below recommended guideline levels (0.05 for lowland rivers) whereas concentrations at estuary sites exceeded guidelines (0.06 and 0.07 at BOYED1 and BOYED2) and exceeded guidelines (0.03 for estuaries and 0.05 for lowland rivers).

Chlorophyll *a* concentrations were much greater at freshwater (BOYPD1-30mg/L and BOYPD2 – 15mg/L) than estuary sites (both <5mg/L). Chlorophyll *a* at freshwater sites exceeded recommended guidelines for lowland rivers by more than three levels of magnitude (0.005mg/L for lowland rivers and estuaries) (ANZECC and ARMCANZ 2000). Measurements for estuarine sites were not sensitive enough (<5mg/L) to provide information relating to compliance levels.

## 4.3 Macroinvertebrates

More than 4566 individuals from 12 different taxa were present in the 2002 summer sampling (Table 5). The majority of this information was gained from the sweep (kicknet) samples as the grab samples contained very few specimens. Despite this, grab samples are considered important to represent the interstitial (spaces between sand grains or gravel) fauna present, in this case the small bivalve *Spaerium sp.* and the dipteran Chaoborinidae. Abundances for grab samples are the total faunal component for all five grabs at each site.

Site BOYPD2 (Mann's Weir) had a higher taxa richness value (26 taxa) than BOYPD1 (Pikes Crossing – 16 taxa). Although AusRIvAS methodology does not allow for quantitative measures of abundance, it does give qualitative relative abundance. For example laboratory notes give good indications of dominants species at sites. Based on pooled taxa the microcrustacea were the most abundant group, representing 71% of the total catch. This group was present in much higher numbers at BOYPD2. Gastropods also represented a substantial proportion of the total catch (9.1%) followed by Dipterans (4.7%) and Odonatans (3.7%). Remaining taxa contributed less than 3% each to total abundance (Table 5).

*Sensitive taxa*

This section considers family richness of the five potentially sensitive taxa – Bivalvia, Decapoda, Ephemeroptera, Gastropoda and Trichoptera. These taxa are widely regarded as either disturbance intolerant or sensitive to stream acidification. Samples from both sites recorded Decapods and Gastropods with Gastropods representing almost 10% of the total abundance. Bivalves were present at large numbers at BOYPD1 (representing 9% of total abundance and Trichopterans were recorded at BOYPD2 (Table 5).

## 4.4 Fish sampling

A total of 383 individuals from 16 species were recorded during the sampling of four sites on the Boyne River in January 2002. The highest abundance of fish occurred within the two middle sites (BOYPD2 and BOYED1) mainly due to the presence of large numbers of *Nematalosa erebi* (bony bream) and *Herklocatsichthys castelnaui* (southern herring) while

remaining sites exhibited lower abundance (BOYPD1 – 87 and BOYED2 – 5 individuals) (Table 6).

Species richness was less variable between freshwater sites with seven and six species present at BOYPD1 and BOYPD2 consecutively. The greatest species richness occurred at estuarine site BOYED1 and the lowest at BOYED2 (five species). Distinct freshwater and estuarine assemblages were apparent with three species common among the sites. These were *Hypseleotris sp.1* (Midgleys carp gudgeon), *Megalops cyprinoids* (oxeye herring or tarpon) and *Mugil Cephalus* (sea mullet). Of individual species *Nematalosa erebi* (bony bream) dominated the freshwater environment and *Herklocatsichthys castelnaui* was the most abundant species at site BOYEDI with 69 individuals caught (Table 6).

Within this study measurements were taken only for target species (mullet). Mean length of *Mugil cephalus* was greater and the individual sizes less variable within freshwater sites (Figure 4). Over all sites, size of *Mugil cephalus* ranged from 140-510cm. Other species besides fish that were caught in the February 2002 sampling are presented in Table 7.

## 4.5 Riparian vegetation

*Reach descriptions*

Reach 1: From the mouth of the Boyne River to the confluence of South Trees. This reach is urbanized, substantially cleared down to the mangrove zone, riparian consisting of primarily mangrove zone which is dominated by *Rhyzophora stylosa* and *Avicennia marina. Cassuarina glauca* was abundant in the terrestrial zone. The river itself is wide and saline with rocky shores.

Reach 2: From South Trees confluence to the S-bend. This reach is non urbanised, but still heavily cleared to the mangrove zone which is characterized by the fringe of *Aegiceras corniculatum* with *Avicennia marina*, some *Rhyzophora stylosa* and some *Exocaria agallocha.* The river is wide and saline here with gravel bars and small rocky islands. Shores are either rocky or steep banks with eroding substrate.

Reach 3: From S-bend to Benaraby Bridge. This reach is still cleared with disturbance from grazing but (mainly on the right hand bank) riparian vegetation is more extensive including *Eucalyptus spp.* (right hand bank more extensive). The mangrove zone forms a narrow fringe dominated by *Aegiceras corniculum* with increased occurrence of *Excoecaria agallocha* and *Avicennia marina* is still abundant in low intertidal zone. *Casuarina glauca* more abundant. The river is narrower and most likely shallower in this section. River banks are reasonably high and above mangroves are stabilised with either rocky ledges or heavily vegetated by grasses.

Reach 4: From Benaraby Bridge to Railway Bridge. This reach's main feature is the gravel extraction process whose road runs half the length of one bank in front of the riparian zone, which is cattle grazed. A substantial proportion of the sites in this reach run through the riverbed itself, therefore *Melaleuca sp.* and *Callistemon sp.* were often prevalent on these long gravel flats. There is a thinning of the mangrove zone. Extensive gravel and cobble bars provide some buffering from tidal influence.

Reach 5: From the Railway Bridge to Mann's Weir. Riparian vegetation appears to be less disturbed in this reach but with some cattle influence. Long gravel flats are still present with *Melaleuca sp.* and *Callistemon viminalis.* This reach has steeper terrain with forested banks and hills. The river is narrower in places with rock and gravel bars.

Reach 6: From Manns Weir to the dam wall. The riparian vegetation is thick and dominated by terrestrial flora species (no mangroves). Land use is variable in this reach with some thick forest vegetation and some heavy clearing. The river is primarily freshwater due to Mann's

Weir forming the salt/fresh interface. There is extensive macrophyte growth in pools and water extraction points along the reach.

*Community composition, structure and extent*

Community composition varied between sites and between reaches. Spatial differences in community structure (using presence absence data) between sites were examined with Bray Curtis dissimilarity measures (Bray and Curtis, 1957) from which site interrelationships were mapped using multidimensional scaling (MDS). In the resultant scattergram, the distance between sites represents their dissimilarity; therefore sites closer together are more similar than sites further apart. The MDS ordination (Figure 5) revealed a general ecological gradient that appeared to move with reaches up the catchment (pictorially left to right). Sites in reaches 1 to 3 were situated on the left of the ordination, sites from reaches 4 and 5 were located centrally and sites from freshwater reach 6 were positioned to the right of the ordination. Species lists for individual sites are available in Appendix 1. Mean species richness was calculated for each reach and is presented in Figure 6. It is obvious that species richness also generally increases up the catchment with mean values ranging from 12 (estuarine reach 1) to 40 (freshwater reach 6) (Figure 2).

Riparian zonation was present in the fringing vegetation at all sites and the number and structural composition of zones varied greatly between sites as well as reaches. Zones present included mangrove zones, sporobolis/marsh weed zones as well as numerous terrestrial vegetation zones and each varied considerably in its structural make-up. The structural components (height and % cover) of zones within each site are presented in Appendix 2 and these tables also show number of plants per zone (stem density). Transect maps also clearly show zonation within individual sites (Appendix 3).

The extent of riparian vegetation varied broadly across sites and reaches (Figure 2). The mean lengths of the riparian hill (which equates with the mean length of the site) per reach are presented in Figure 7 and Figure 2. Stem numbers gave absolute measures of abundance for each species and zone (excluding grasses and weeds for which a relative abundance was given). Mean stem numbers per reach are presented in Figure 8a, while numbers of stems per zone are available in Appendix 1 (and Figure 2). Stem numbers per site were initially high from the mouth of the river to S bend past South Trees confluence (Reaches 1 and 2 - Figure 2), lower in the mid sections of the river (reaches 3, 4 and 5) and highest in the freshwater stretch of the river (reach 6) (Figure 9). To standardize for the differing site lengths, mean stem density (stems per ha) was also calculated (figure 8b). This figure confirms that stem densities were highest in reaches 1 and 2 and lowest in the mid reaches. Percent foliage protective cover provided a measure of the canopy cover for each site and mean values for each reach are provided in Figure 9. This figure shows initially high foliage cover (47%) within reach 1 (mouth of river to South Trees confluence), which decreased substantially in reach 2 (12%) and then generally increased upstream (reach 3 - 30%, reach 4 - 22%, reach 5 - 37%, reach 6 - 52%) (Figure 2).

## 5.0 Discussion

*Aquatic habitat assessment*

There was a diverse array of microhabitats present within the two freshwater and two estuarine study sites in the Boyne River during the course of this study and each site was allocated a high aquatic rating. There was, however, some evidence of eutrophication within both freshwater and estuarine pools, apparent by the elevated nutrient levels at these sites. Most catchment nutrients are derived from either wastewater discharges or diffuse runoff within the catchment and the significance of diffuse sources depends on the yield of nutrient from the land-use activity and the proportion of the catchment devoted to that activity (i.e. nutrient kg/ha/a). Generally, the highest yields of nutrients are from urban areas, with

successively lower yields from agricultural and forested catchments (Campbell & Doeg 1989 in ANZECC and ARMCANZ 2000). Phosphorus is thought to be the primary limiting nutrient in freshwater systems, and this appears to be the case in the present study, apparent by the high TN:TP ratio (15 and 25) at fresh sites (Donnelly et al 1998). Based on the Redfield ratio, phosphorus limitation is expected when the TN:TP ratio is >15 and nitrogen limitation is expected when the TN:TP ration falls below 15 (Robertson 1997). This highlighted the difference from estuarine sites, where nitrogen appeared to be the primary limiting nutrient (3.3 and 2.9 at BOYED1 and BOYED2 respectively). High levels of phosphorus within estuary sites suggest caution for river managers. With phosphorus widely accepted as the key nutrient of eutrophication and algal problems, increased levels can provide advance warning (Cullen 2001). The large amounts of macrophytes present at freshwater sites were further testimony to eutrophied conditions, as were the low oxygen levels at all sites. Very low oxygen concentrations are common in nutrient enriched water bodies as the nutrients stimulate proliferation of oxygen consuming microbes (ANZECC and ARMCANZ 2000). Additionally, the floating attached macrophytes that flourish here create an air/water interface, which may further limit entry of oxygen to the water body. The high levels of chlorophyll *a* were additional evidence of eutrophication. The large increase in conductivity at BOYPD2 (Mann's weir site) at 2 metres was indicative of the salt wedge present at this site.

Despite the water quality implications there were reasonably diverse assemblages of fish (all sites) and macroinvertebrates (freshwater sites) present throughout the river. Although the dominant fish species within freshwaters, *Nematolosa erebi* (bony bream), are quite robust concerning variation in some water quality parameters (temperature and pH) they have a low tolerance of oxygen depletion and among the species most affected by river flow alteration and regulation (Gehrke and Harris 2001). Migratory fish present included *Megalops cyprinoids* (oxeye herring or tarpon) and *Mugil cephalus* (sea mullet), the latter of which are a target species of this study (Native Fish Australia 2004). The greater size variability and smaller sizes of mullet within the estuarine regions most likely reflects their use of this area for grow out. Macroinvertebrate assemblages provide a good indication of river health; as they are abundant and diverse and are sensitive to changes in water quality, flow regime and habitat conditions. Presence of the more sensitive taxa within the present study, including decapods, bivalves, trichopterans and large numbers of gastropods, was indicative of reasonably healthy conditions. The relative abundances were also indicative of healthy conditions as unhealthy environments often result in domination by few species. However, due to the qualitative nature of the methodology, abundance measures employed do not provide absolute numbers; therefore any interpretation attached to this parameter is limited. It is advised that future methodology should consider the advantages of quantitative abundance measures.

*Riparian vegetation*

The riparian monitoring program established in 2002 provides the basis for future detection of change in the riparian communities on the Boyne River. Although results were presented in this report by reaches for ease of assimilation, it is the ability of individual sites to detect absolute change in certain parameters (species composition, stem numbers, zone lengths etc) over time, that gives this methodology the integrity required for high level monitoring and interpretation.

Several general trends were apparent when examining the mean reach results. Species diversity generally increased while moving upstream. This result reflects the low diversity attached to extensive mangrove zones and the limited terrestrial vegetation zones (due to suburban development and /or clearing) present in reaches 1, 2 and 3. Reaches 4 and 5 contained reduced or absent mangrove zones and the most extensive terrestrial zones, but many sites ran across large parts of gravel river bed that were depauperate in species, hence their median diversity (the higher mean diversity within reach 4 compared to 5 is due to

additional grass and weed species rather than greater tree and shrub diversity). The river at the uppermost reach (freshwater reach 6) was wider and deeper (due to Mann's Weir impoundment) and, therefore (although sites in this reach were smaller then sites in reaches 4 and 5), the riparian zone was reasonably extensive from the river edge to the top of the ridge (lack of dry gravel bed).

Differences in the length of the riparian ridge (length of the site) across reaches followed reasons discussed above. This parameter increased upstream reflecting the limited riparian zones (reaches 1 and 2), increasing in size due to wide dry riverbed zones containing limited vegetation (reaches 3 and 4). The decreases in ridge length in reaches 5 and 6 reflect decreased dry riverbed areas rather than reduced riparian ridge zones.

Stem densities and percent cover of riparian foliage appeared to generally follow a similar concave pattern graphically; initial high density and cover towards the river mouth decreased to lower density and cover through the mid reaches, and increased again in the uppermost reaches. This pattern is due to the high density of mangroves present in the lower reaches (despite the reduced terrestrial vegetation zones in this area) giving way to decreased or absent mangroves and sparse dry riverbed vegetation coupled with small riparian ridges. The reduction of mangroves is related primarily to smaller intertidal zones and changes in substrate from the lower river reaches. Ridge lengths then increase further up the catchment and vegetation thickens from the river itself, resulting in the upward curve. One contrast in this pattern of stem densities and canopy cover was evident. The low canopy cover compared to the very high stem densities within reach 2 was principally due to large areas of dense mangroves which were below breast height and therefore didn't register as canopy as well as very limited terrestrial vegetation (and hence canopy) within this reach.

The differences in community structure whilst moving upstream (as were evident from the MDS ordination) reflect the relative distribution of species, primarily due to germination conditions, disturbance regimes and hydrology (Melzer 1999). In lower reaches plant species are generally more disturbance adapted with communities including mangrove and saltpan species, *Casuarina* spp. and remnant eucalypt woodland. However, in the upper reaches (particularly freshwater reach 6) communities include littoral and dry rainforest species (e.g. *Arytera divaricata, Aphananthe* spp, *Alectryon* spp, *Cupaniopsis anacardioides*, *Canthium* spp etc) within remnant patches of semi evergreen vine thicket (BRAIN, 1995). Vine thicket has the structural and floristic characteristics of rainforest but because of its smaller height cannot be considered forest (Floyd, 1990). The micro habitat (ground moisture and/or protection from winds and frosts) created within these sites allows for growth of species such as *Adiantum* spp (ferns). Many species associated with these sorts of communities have a highly localized or scattered distribution and are now uncommon due to extensive clearing and modification to habitat in the Central Queensland area. Primary threats to these communities include fire, clearing and water availability.

## 6.0 Acknowledgements

We would like to thank the CEM Technical Services Division, including Damon Shearer, Michael Price, Shona Marks and Andrew Davis for assisting in extensive fieldwork schedules and skippering of the research vessels. Thank you to the Gladstone Botanical Gardens, Alistair Melzer and Rebecca Hendry for plant identification. We gratefully acknowledge the site maps by Wayne Boyd (GAWB GIS officer) and the project support by Natalie Madden (formerly GAWB environmental officer).

## 7.0 References

Abal, E.G., Moore, K.B., Gibbes, B.R. and Dennison, W.C. (2002) State of South-east Queensland Waterways Report 2001, Moreton Bay Waterways and Catchments Partnership, Brisbane 4001.

Allen, G.R., Midgley, S.H., Allen, M. (2002) Field Guide to the Freshwater Fishes of Australia. Western Australian Museum. Perth. WA.

ANZECC and ARMCANZ (2000) The Australian and New Zealand guidelines for fresh and marine water quality, Volume 2, Chapter 8 – Aquatic ecosystems. National Water Quality Management Strategy Paper No 4. Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand.

Australian Standard AS 5567.0. (1998) Method for appropriate usage of field equipment. Standards Association of Australia.

Boyd, W. (2004) Personal communication, Gladstone Area Water Board, Gladstone 4680.

BRAIN (Brisbane Rainforest Action and Information Network (1995) http://www.brisrain.webcentral.com.au

Dean, J.C. (1991) Key to Larval Trichoptera. Insects of Australia: A textbook for students and research workers. CSIRO University Press, Melbourne.

Department of Natural Resources and Mines (2001) Queensland Australian River Assessment System (AusRivAS) Sampling and Processing Manual. Queensland Department of Natural Resources and Mines.

DNR&M (2000) Waterwatch Draft Manual. Queensland Department Of Natural Resources and Mines.

Donnelly, T.H., Barnes, C.J., Wasson, R.J. Murray, A.S. and Shart, D.L. (1998) Catchment phosphorus sources and algal blooms - an interpretive review. CSIRO Land and Water, Canberra, ACT, 2601.

Floyd A.G. (1990) Australian rainforests in New South Wales. Vol. 2. Surrey Beatty and Sons & NSW National Parks and Wildlife Service, Sydney

Gehrke, P.C. and Harris, J.H. (2001) Regional-scale effects of flow regulation on lowland riverine fish communities in New South Wales. *Regulated Rivers-Research & Management.* 17:369-391.

Grant, E. (1999) Grants guide to fishes. Grant PTY LTD, Redcliffe, QLD.

Melzer, A. (1999) Terrestrial Ecology In Water Management Plan (Boyne River Basin) Gladstone Area Water Board, Gladstone.

Native Fish Australia (2004) Fish Files. http://www.nativefish.asn.au/fish.html .

Natural Resources and Mines, Queensland Government (2003) Boyne River Basin resource operations plan. Department of Natural Resources and Mines, QLD.

Robertson, A. (1997) Limiting nutrient workshop 1997, LWRRDC Occasional paper 7/99. Land and Water Resources Development Act, ACT.

Robarts, K. (2003) Summary and Recommendations In Proceedings if the National Workshop in phosphorus in Australian freshwaters. Land and Water Resources Research and Development Cooperation Occasional Paper 03/93.

Sinclair Knight Merz (1999) Environmental data collection and monitoring program. Sinclair Knight Merz, QLD.

Stanley, T.D. and Ross, E.M. (1989) Flora of South-eastern Queensland, Volume 3. Queensland Department of Primary Industries, Queensland Government.

TPS Pty Ltd. (1994) TPS – 90FLMV Microprocessor Field Analyser Manual, TPS Pty Ltd. Brisbane, QLD.

Williams, W.D. (1980) Australian Freshwater Life. The Macmillan Company of Australia, Melbourne.

Zang, A.D. (2001) Filterable phosphorus partitioning in wetland waters: variability and bioavailability. Maters Thesis. University of Western Australia, Centre for Water Research, reference ED 1348 AZ 2001,ED 1348.

Table 1: Aquatic ecosystems monitoring requirements specified in Resource Operations Plan (NR&M) to be addressed in the aquatic monitoring survey of fish and aquatic habitats in 2004.

| hypothesis number | parameter | site location | frequency of sampling |
|---|---|---|---|
| 2 | aquatic habitat[1] assessment:<br>identify habitat types<br>map habitat | Pikes Crossing Pondage & Manns Weir Pondage | twice per year - during September to November and March to May plus after a trigger flow period |
| 2 | riparian vegetation: fresh<br>community structure<br>extent<br>composition | Pikes Crossing Pondage & Manns Weir Pondage | years 1[2], 5 and 9 during the same season after the comencement of ROP and after a defined flood event[3] |
| 10 | riparian vegetation: estuary<br>community structure<br>extent<br>composition | Benarably Estate & south Trees or alternative sites as determined by the chief executive | years 1[2], 5 and 9 during the same season after the comencement of ROP and after a defined flood event |
| 5 & 6 | fish:<br>species diversity and abundance<br>community composition<br>community age structure | at least three sites, being upstream and downstream of Mann's Weir plus Benaraby Estate, or an alternative estuary site as agreed to by chief executive | at least once per year - in early September prior to a trigger flow even and if a trigger flow even occurs, after that trigger flow event[3] |

1: habitat may include, but is not limited to pools, riffles, sandy bars, large woody debris, substrate type, macrophytes and riparian vegetation.

2: year 1 may be within 12 months prior to commencement of the ROP.

3: a "flood event" is a flow calculated by the Boyne River pre-development case IQQM that occurs 1 in ever 10 years or larger.

Table 2: Broadscale inventory classifications of sites in the Boyne River in August 2001.

| Site | BOYPD1 | BOYPD2 | BOYED1 | BOYED2 |
|---|---|---|---|---|
| Date | 26/08/2001 | 26/08/2001 | 15/08/2001 | 16/08/2001 |
| Easting | 24o03.039 | 24o02.073 | 24o00.379 | 24o58.566 |
| Northing | 151o19.438 | 155o19.213 | 151o20.446 | 151o19.759 |
| Width | 40-60 | 50-60 | 60 | 160-200 |
| Length | 900 | 1500-2000 | 2000 | 2000 |
| Depth | 3-5 | 3-5 | 3-4 | 4-5 |
| Disturbance | moderate | moderate | moderate | moderate |
| Left instability | low | low | low | moderate |
| Right instability | low | moderate | low | moderate |
| Left erodibility | low | low | low | moderate |
| Right erodibility | low | moderate | low | moderate |
| Bed stability | high | high | high | high |
| LeftRiparianWidth | 20-30 | 5-15 variable | 100 | 120 |
| RightRiparianWidth | 10-15 | 15-20 | 60 | 60 |
| AquaticHabitatRating | high | high | high | high |

Table 3: Water quality measurements at four sites on the Boyne River in January 2002.

| Site | Date | Time | Depth (m) | DO (ppM) | DO (%) | Conductivity (uS/cm) | pH | Temp oC |
|---|---|---|---|---|---|---|---|---|
| BOYPD1 | 23/01/2002 | 16:36 | 0.1 | 3.33 | 43 | 363.0 | 6.7 | 28.4 |
| | | 16:37 | 1 | 0.36 | 5 | 372.0 | 6.6 | 27.9 |
| | | 16:38 | 2 | 0.04 | 5 | 372.0 | 6.5 | 27.4 |
| | | 16:39 | 3 | 0.04 | 5 | 383.0 | 6.2 | 26.9 |
| | | Mean | 1.5 | 0.94 | 12 | 372.5 | 6.48 | 27.7 |
| BOYPD2 | 29/01/2002 | 16:11 | 0.1 | 4.80 | 66 | 511.0 | 6.5 | 32.5 |
| | | 16:14 | 1 | 1.63 | 23 | 557.0 | 6.4 | 28.7 |
| | | 16:15 | 2 | 1.78 | 23 | 5380.0 | 6.4 | 29.4 |
| | | Mean | 1.0 | 2.74 | 36 | 2149.3 | 6.4 | 30.2 |
| BOYED1 | 21/01/2002 | 16:52 | 0.1 | 5.19 | 68 | 35700.0 | 7.8 | 30.0 |
| | | 16:49 | 1 | 5.09 | 66 | 36300.0 | 7.4 | 29.3 |
| | | 16:49 | 2 | 4.27 | 56 | 37100.0 | 7.4 | 28.9 |
| | | 16:50 | 3 | 4.06 | 53 | 37800.0 | 7.4 | 28.8 |
| | | 16:51 | 4 | 4.12 | 54 | 38200.0 | 7.5 | 28.9 |
| | | 16:51 | 5 | 4.10 | 54 | 38400.0 | 7.5 | 29.0 |
| | | Mean | 2.5 | 4.47 | 58 | 37250.0 | 7.5 | 29.2 |
| BOYED2 | 22/01/2002 | 17:13 | 0.1 | 5.19 | 68 | 42000.0 | 7.4 | 29.8 |
| | | 17:14 | 1 | 5.11 | 68 | 43100.0 | 7.5 | 29.9 |
| | | Mean | 0.6 | 5.15 | 68 | 42550.0 | 7.4 | 29.9 |

Table 4: Water nutrient measurements at four sites on the Boyne River in January 2002.

| Site | BOYPD1 | BOYPD2 | BOYED1 | BOYED2 |
|---|---|---|---|---|
| Date | 23/01/2002 | 29/01/2002 | 21/01/2002 | 22/01/2002 |
| Suspended Solids (mg/L) | 22 | 6 | 22 | 22 |
| Ammonia (mg/L) | 0.03 | 0.02 | 0.02 | <0.01 |
| Nitrate (mg/L) | <0.01 | <0.01 | <0.01 | <0.01 |
| Nitrite & Nitrate (mg/L) | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Kjeldahl N (mg/L) | 0.6 | 0.5 | 0.2 | 0.2 |
| Total N (mg/L) | 0.6 | 0.5 | 0.2 | 0.2 |
| Total P (mg/L) | 0.04 | 0.02 | 0.06 | 0.07 |
| Reactive P (mg/L) | <0.01 | <0.01 | 0.03 | 0.03 |
| Chlorophyll a ($mg/m^3$) | 30 | 15 | <5 | <5 |

Table 5: Family richness and abundance of macroinvertebrates caught during sampling of the Boyne River in February 2002.

| Taxa | Genus species | BPD1(k) | BPD2(k) | BPD1(g) | BPD2(g) | % Abundance |
|---|---|---|---|---|---|---|
| **Bivalve** | | **0.0** | **0.0** | **35.3** | **0.0** | **0.8** |
| Sphaeridae | Sphaerium sp. | 0.0 | 0.0 | 35.3 | 0.0 | 0.8 |
| **Coleoptera** | | **30.0** | **20.0** | **0.0** | **0.0** | **1.1** |
| Hydrophilidae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| Dytiscidae larvae | | 30.0 | 10.0 | 0.0 | 0.0 | 0.9 |
| **Crustacea** | | **>3000** | **>240** | **0.0** | **0.0** | **71.0** |
| Cladocera | | >100 | >100 | 0.0 | 0.0 | 4.4 |
| Copepoda | Cyclopoides | >100 | 60.0 | 0.0 | 0.0 | 3.5 |
| Ostracod | | >100 | 80.0 | 0.0 | 0.0 | 3.9 |
| **Decapoda** | | **10.0** | **>100** | **0.0** | **0.0** | **2.4** |
| Atyidae | | 10.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| Palaemonidae | | 0.0 | >100 | 0.0 | 0.0 | 2.2 |
| **Diptera** | | **90.0** | **>100** | **22.8** | **0.0** | **4.7** |
| Chironomidae | | 30.0 | >100 | 0.0 | 0.0 | 2.8 |
| Ceratopogonidae | | 10.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| Culicidae | | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 |
| Culicidae | (SF)Chaoborinidae | 0.0 | 0.0 | 20.8 | 0.0 | 0.5 |
| Culicidae | (SF)Culicinae, (T)Culicine | 40.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| Culicidae | (SF)Culicinae, (T)Anophelini | 10.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| **Gastropod** | | **180.0** | **>230** | **2.5** | **5.0** | **9.1** |
| Planorbidae | Segnitila sp. | 80.0 | 0.0 | 2.5 | 0.0 | 1.8 |
| Planorbidae | Amerianna sp. | 0.0 | 30.0 | 0.0 | 0.0 | 0.7 |
| Hydrobiidae | | 100.0 | >100 | 0.0 | 5.0 | 4.5 |
| Thiariidae | | 0.0 | >100 | 0.0 | 0.0 | 2.2 |
| **Hemiptera** | | **40.0** | **50.0** | **0.0** | **0.0** | **2.0** |
| Hemiptera: Heteroptera | | 20.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| Pleidae | | 20.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| Hydrometridae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| Belestomatidae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| Geriidae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| Naucoridae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| Curculionidae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| **Lepidoptera** | | **0.0** | **10.0** | **0.0** | **0.0** | **0.2** |
| Pyralidae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| **Odonata** | | **40.0** | **130.0** | **0.0** | **0.0** | **3.7** |
| Austrcordulidae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| Aeshnidae | | 0.0 | 10.0 | 0.0 | 0.0 | 0.2 |
| Coenagrionidae | | 0.0 | 20.0 | 0.0 | 0.0 | 0.4 |
| Libellulidae | | 10.0 | 50.0 | 0.0 | 0.0 | 1.3 |
| Lindeniidae | | 10.0 | 10.0 | 0.0 | 0.0 | 0.4 |
| Protoneuridae | | 20.0 | 30.0 | 0.0 | 0.0 | 1.1 |
| **Oligochaete** | | **20.0** | **70.0** | **0.0** | **0.0** | **2.0** |
| Oligochaete | | 20.0 | 70.0 | 0.0 | 0.0 | 2.0 |
| **Picies** | | **0.0** | **90.0** | **0.0** | **0.0** | **2.0** |
| Hypseleotris sp. | | 0.0 | 90.0 | 0.0 | 0.0 | 2.0 |
| **Trichoptera** | | **0.0** | **50.0** | **0.0** | **0.0** | **1.1** |
| Leptoceridae | | 0.0 | 50.0 | 0.0 | 0.0 | 1.1 |
| **Family richness** | | **17.0** | **26.0** | **3.0** | **1.0** | **36.0** |
| **Total abundance** | | **>3410** | **>1090** | **60.7** | **5.0** | **4566.0** |

Table 6: Species richness and abundance of fish caught during sampling of the Boyne River in January 2002.

| Scientific Name | Common Name | BOYPD1 | BOYPD2 | BOYED1 | BOYED2 | Total |
|---|---|---|---|---|---|---|
| *Acanthopagrus australis* | Sea bream | 0 | 0 | 1 | 0 | 1 |
| *Ambassis agassizii* | Olive Perchlet | 10 | 7 | 0 | 0 | 17 |
| *Ambassis marianus* | Estuary perchlet/ Glass perch | 0 | 0 | 3 | 2 | 5 |
| *Arius graeffei* | Blue Catfish or Lesser Salmon Catfish | 2 | 12 | 0 | 0 | 14 |
| *Drepane punctata* | Sickle fish | 0 | 0 | 1 | 1 | 2 |
| *Gerres subfasciatus* | Common Silverbelly | 0 | 0 | 2 | 1 | 3 |
| *Glossamia aprion* | Mouth Almighty | 6 | 1 | 0 | 0 | 7 |
| *Herklotsichthys castelnaui* | Southern Herring | 0 | 0 | 69 | 1 | 70 |
| *Hypseleotris species 1* | Midgley's Carp Gudgeon | 2 | 1 | 1 | 0 | 4 |
| *Leiognathus moretoniensis* | Black banded Ponyfish | 0 | 0 | 1 | 3 | 4 |
| *Marilyna pleurosticta* | Banded toadfish | 0 | 0 | 1 | 0 | 1 |
| *Megalops cyprinoides* | Oxeye Herring/Tarpon/Bony Mullet | 4 | 0 | 11 | 0 | 15 |
| *Mugil cephalus* | Sea mullet | 2 | 5 | 18 | 0 | 25 |
| *Nematalosa erebi* | Bony Bream | 61 | 152 | 0 | 0 | 213 |
| *Plectorrhinchus gibbosus* | Brown Butterlips | 0 | 0 | 1 | 0 | 1 |
| *Scatophagus argus* | Spotted Butter fish | 0 | 0 | 1 | 0 | 1 |
| Abundance | | 87 | 178 | 110 | 8 | 383 |
| Species richness | | 7 | 6 | 12 | 5 | 16 |

Table 7: Species richness and abundance of other animals caught during sampling of the Boyne River in January 2002.

| Scientific Name | Common Name | BOYPD1 | BOYPD2 | BOYED1 | BOYED2 | Total |
|---|---|---|---|---|---|---|
| *Macrobrachium sp.* | Freshwater shrimp | 0 | 14 | 35 | 0 | 49 |
| *Penaeus merguiensis* | Banana prawn | 0 | 0 | 20 | 2 | 22 |
| *Penaeus monodon* | Tiger prawn | 0 | 0 | 1 | 0 | 1 |
| *Penaeus sp.* | Juvenile prawn | 0 | 0 | 0 | 7 | 7 |
| *Scylla serrata* | Mudcrab | 0 | 0 | 0 | 1 | 1 |
| Abundance | | 0 | 14 | 56 | 10 | 80 |
| Species richness | | 0 | 1 | 3 | 3 | 5 |

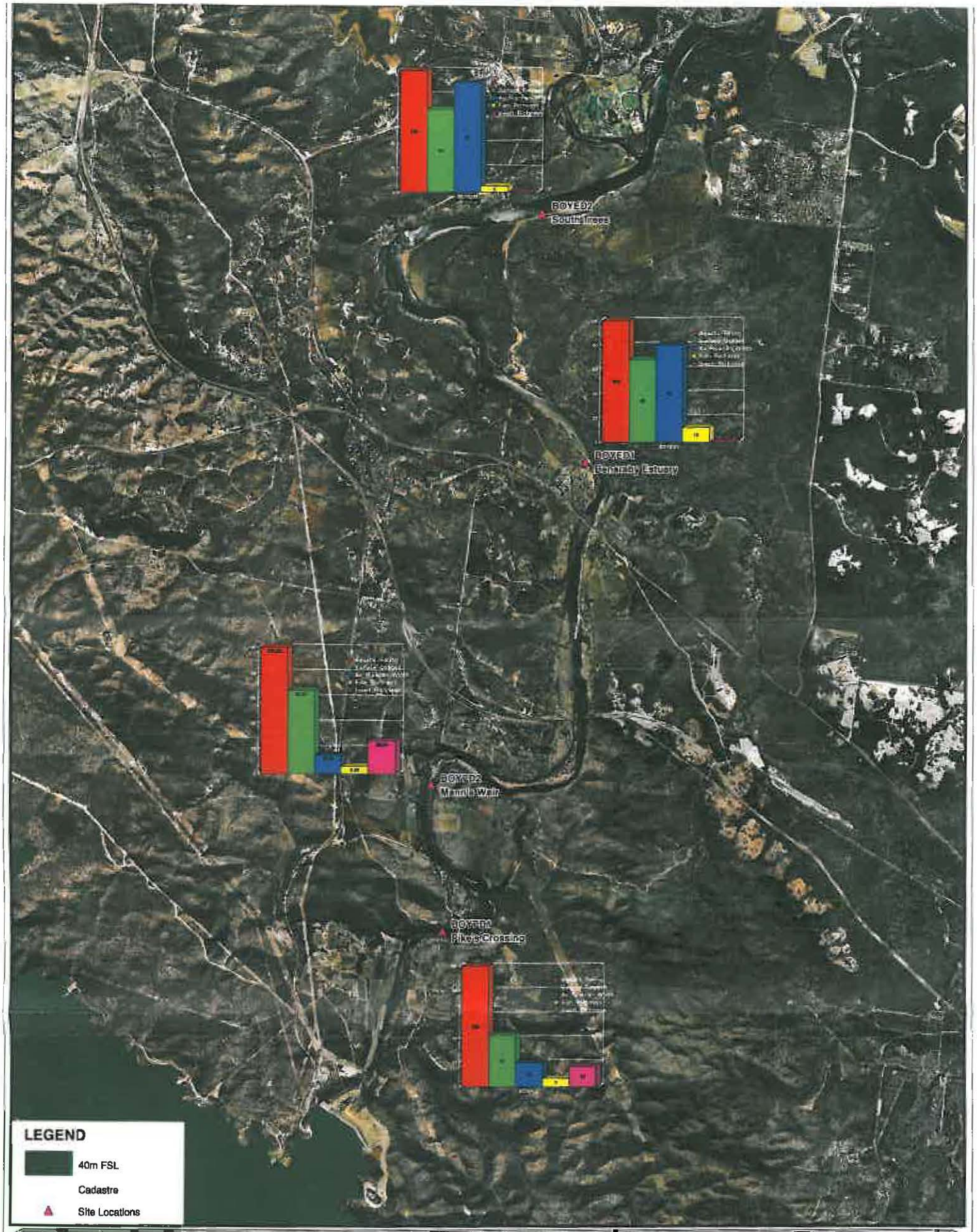


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**Figure 1**

**Map Showing Four Sites Monitored in 2002 and Biological Results**

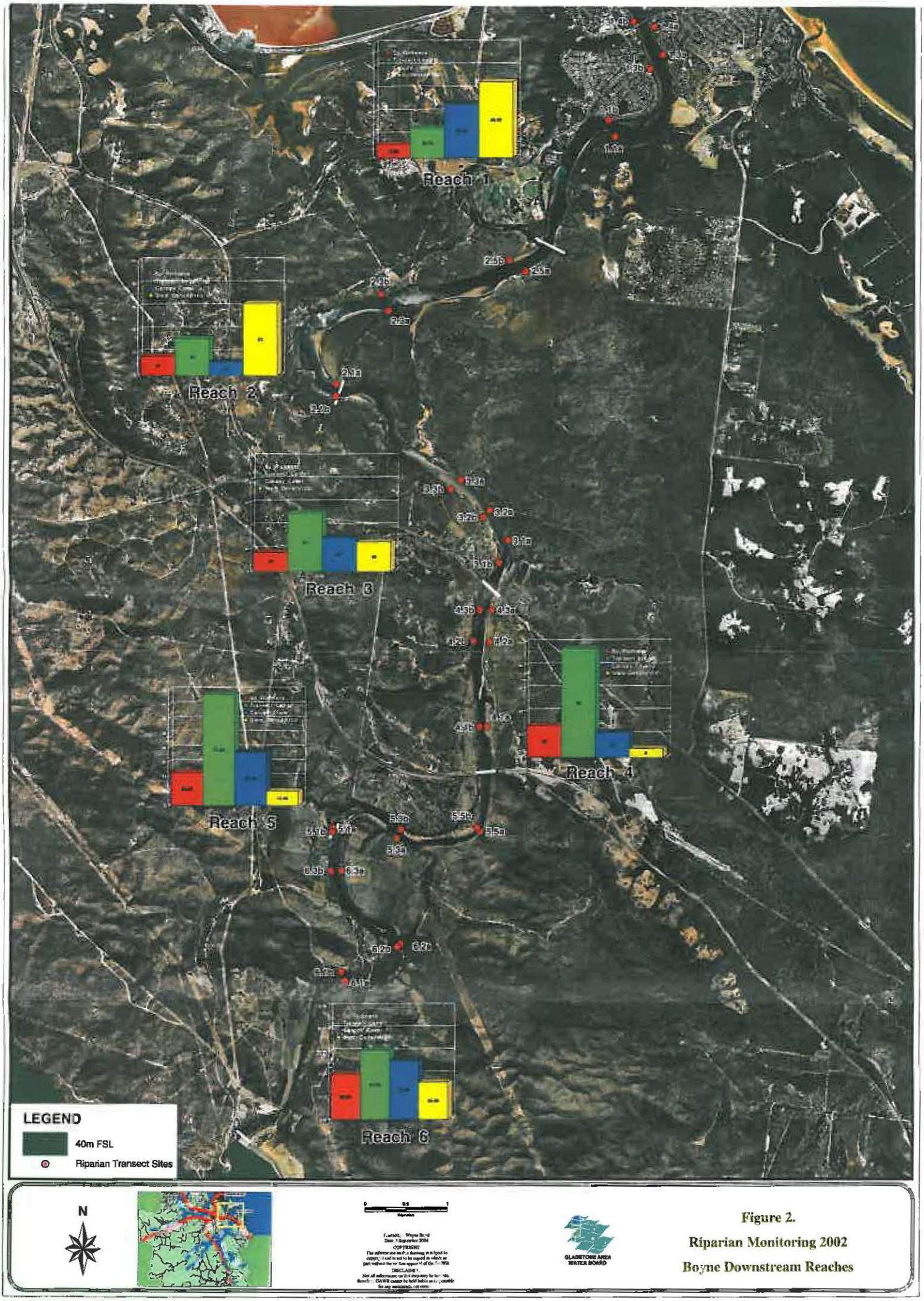


**Figure 2.**

**Riparian Monitoring 2002**

**Boyne Downstream Reaches**

Figure 3a and b: Erosion on the left bank of BOYED2 on the Boyne River in August 2001.

(a)

(b)

Figure 4: Mean length distribution of *Mugil cephalus* captured at three sites on the Boyne River in January 2002 (maximum and minimum lengths are shown as error bars).

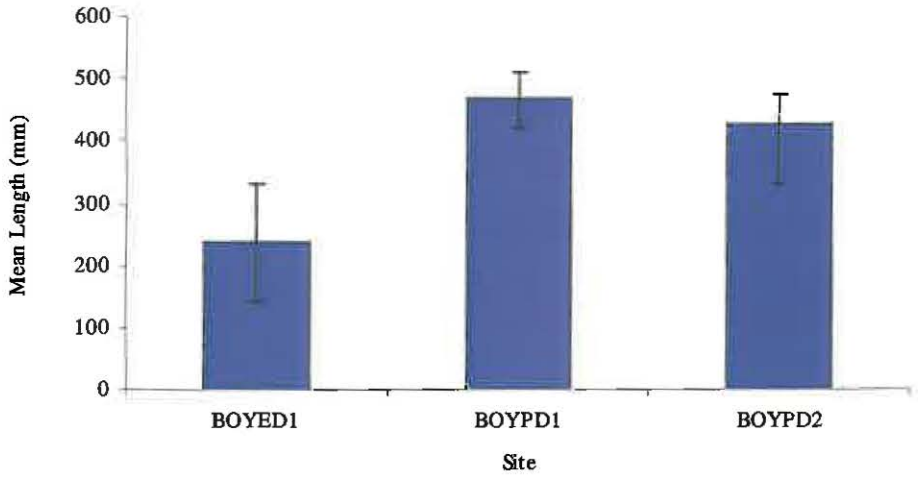


Figure 5: MDS ordination of Bray Curtis dissimilarity measures for community structure of riparian sites (and reaches 1-6 by symbol).

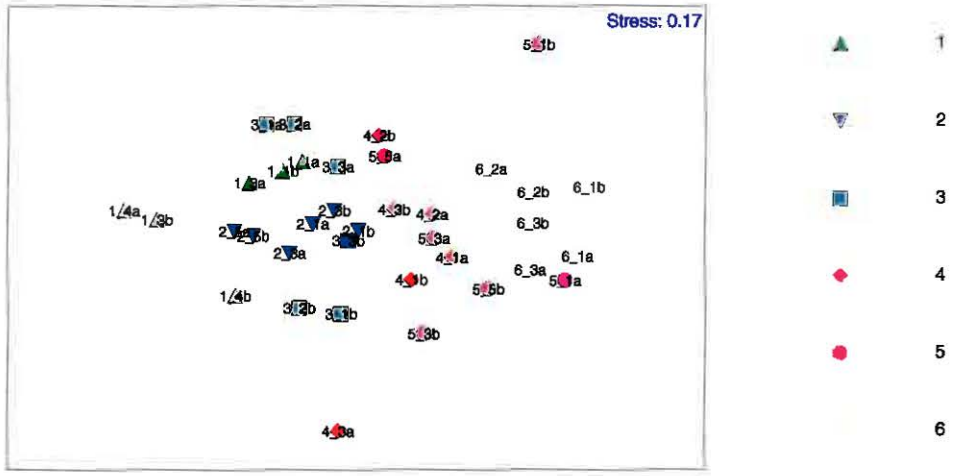

Figure 6: Mean species richness values at six riparian reaches on the Boyne River in 2002 (values are calculated from the species richness of six sites in each reach).

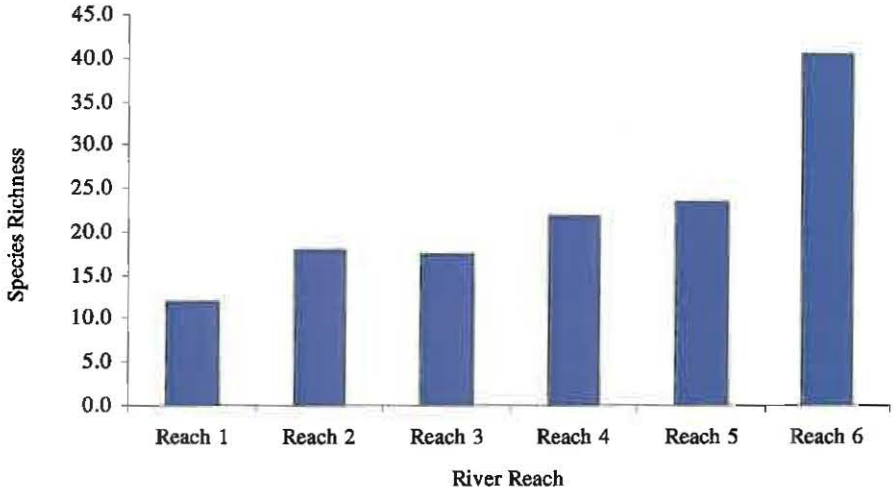


Figure 7: Mean length of the riparian ridge at six reaches on the Boyne River in 2002 (values are calculated from the lengths of six riparian sites in each reach).

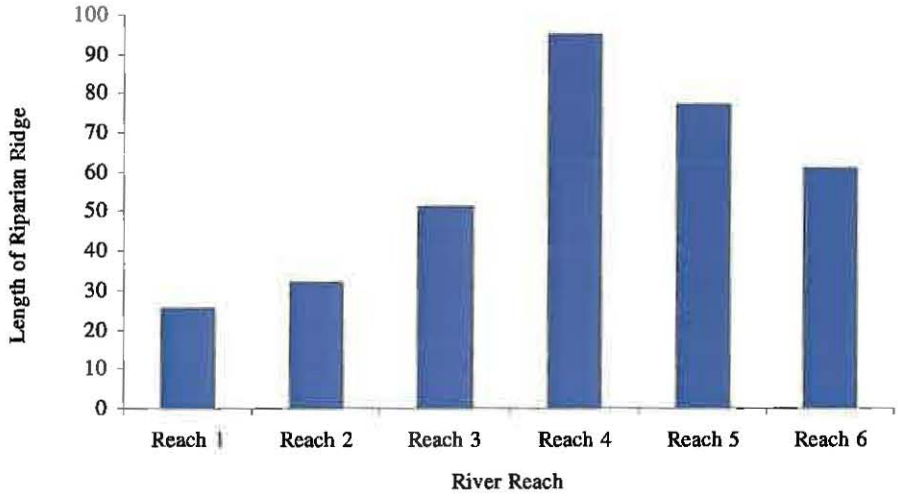

Figure 8a: Mean stem numbers of riparian vegetation at six reaches on the Boyne River in 2002 (values are calculated from the stem numbers of six riparian sites at each ridge).

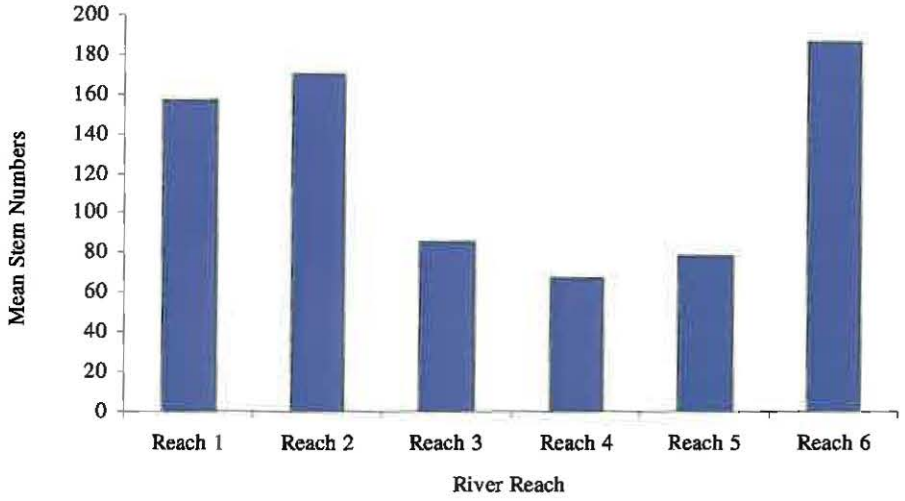


Figure 8b: Mean stem density (stems per ha) of riparian vegetation at six reaches on the Boyne River in 2002 (values are calculated from the stem densities of six riparian sites at each ridge).

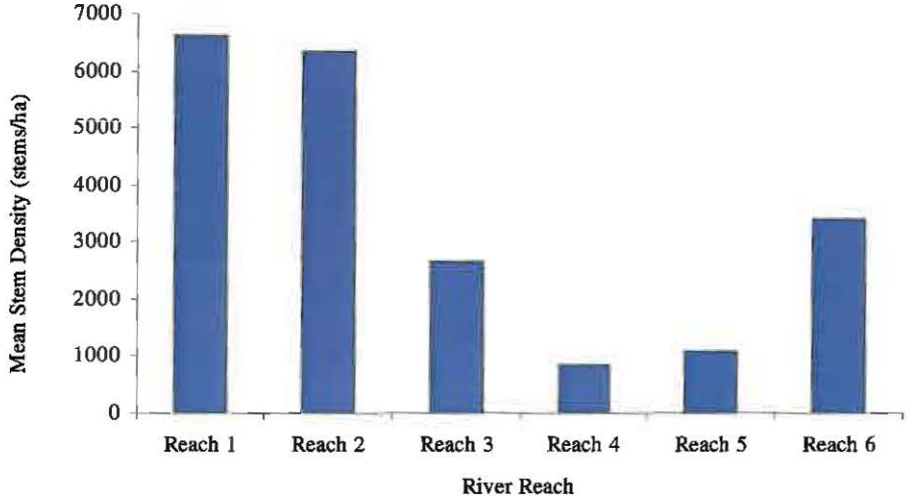

Figure 9: Mean % cover of riparian foliage at six reaches on the Boyne River in 2002 (values are calculated from the % covers of six riparian sites in each reach).

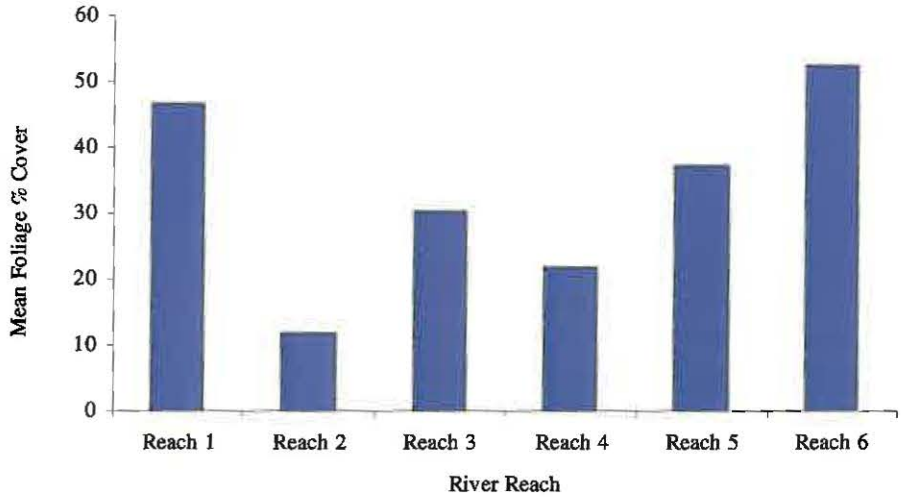

Plate 1: BOYPD1 left bank upstream

Plate 2: BOYPD1 left bank downstream

Plate 3: BOYPD1 right bank upstream

Plate 4: BOYPD1 right bank downstream

Plate 5: BOYPD2 left bank upstream

Plate 6: BOYPD2 left bank downstream

Plate 7: BOYPD2 right bank upstream

Plate 8: BOYPD2 right bank downstream

Plate 9: BOYED1 left bank upstream

Plate 10: BOYED1 left bank downstream

Plate 11: BOYED1 right bank upstream

Plate 12: BOYED1 right bank downstream

Plate 13: BOYED2 left bank upstream

Plate 14: BOYED2 left bank downstream

Plate 15: BOYED2 right bank upstream

Plate 16: BOYED2 right bank downstream

Appendix 1: Species present at 36 riparian monitoring sites within six reaches on the Boyne River in 2002 and 2004.

| Reaches | Reach 1 | | | | | | Reach 2 | | | | | | Reach 3 | | | | | | Reach 4 | | | | | | Reach 5 | | | | | | Reach 6 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1_1a | 1_1b | 1_3a | 1_3b | 1_4a | 1_4b | 2_1a | 2_1b | 2_3a | 2_3b | 2_5a | 2_5b | 3_1a | 3_1b | 3_2a | 3_2b | 3_3a | 3_3b | 4_1a | 4_1b | 4_2a | 4_2b | 4_3a | 4_3b | 5_1a | 5_1b | 5_3a | 5_3b | 5_5a | 5_5b | 6_1a | 6_1b | 6_2a | 6_2b | 6_3a | 6_3b | Total |
| Acacia aulacocarpa | X | X | X | | | X | | X | | X | | | | | | | X | X | X | | X | X | | X | X | | X | X | X | X | X | X | X | X | X | X | 23 |
| Acacia decora | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | 1 |
| Acacia farnesiana | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Acacia flavescens | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | 1 |
| Acacia podalyriifolia | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Acacia sp | | | | | | | | | | | | | X | | X | | | | | | | | X | | | | | | | | | | | | | | 3 |
| Acrostichum speciosum | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Adiantum aethiopicum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Adiantum sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | 2 |
| Adiantum trapeziforme | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Aegeratum houstonianum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | 2 |
| Aegialitis annulata | | | | | | X | | | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| Aegiceras corniculatum | X | X | X | X | | | X | X | X | X | X | X | X | X | X | X | X | X | | X | | X | | X | | | | | | | | | | | | | 19 |
| Alectryon connatus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Alectryon subdentatus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Alectryon tomentosus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Alectryon unilobatus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | 1 |
| Alphitonia excelsa | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | X | | | | | | X | 3 |
| Alstonia constricta | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | 1 |
| Alternanthera sp | | | | | | | | | | | | | | | | | | | | | X | X | | | X | | | | | | X | | | | | | 4 |
| Alyxia ruscifolia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | 2 |
| Aphananthe philippinensis | | | | | | | | | | | | | | | | | | | X | X | | | | | X | | X | | | X | X | X | | X | X | X | 10 |
| Aphananthe sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Aristida sp | X | | | | | | | X | | X | | | | | | | X | | X | X | X | X | | | | | | | | | | X | | | | | 9 |
| Aristolochia elegans | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | 1 |
| Aristolochia sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | 1 |
| Arundinella nepalensis | X | | | | | | | X | | | | | X | | X | | X | | | | | X | | | | | | | X | | | X | X | | | | 9 |
| Arytera divaricata | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Austrosteenisia blackii | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Avicennia marina | X | X | X | X | X | X | X | X | X | X | X | X | | | | X | X | | | | | | | | | | | | | | | | | | | | 14 |
| Bacopa sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Bidens pilosa | | | | | | | X | X | X | | | | | X | | | | | X | X | | | | X | X | | | | | | X | | | | X | | 10 |
| Bothriochloa decipiens | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | 1 |
| Bothriochloa sp | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | 1 |
| Brachiaria mutica | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 2 |
| Breidelia leichardtii | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Breynia oblongifolia | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | X | | 4 |
| Bridelia leichardtii | | | | | | | | | | | | | | | | X | | | X | | | | | | X | | | | | X | X | | | X | X | 7 |
| Bruguiera gymnorrhiza | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Bryophyllum daigremontianum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Bryophyllum serrulatum | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Bryophyllum sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | 2 |
| Bryophyllum tubiflorum | | | | | | | | | | X | | | | | | | | | X | | | | X | X | | | | | | | | | | | | | 4 |
| Bursaria incana | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | 1 |
| Bursaria sp | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | 1 |
| Cajanus marmaratus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Callistemon pinifolia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Callistemon viminalis | | | | | | | | | | | | | | | | | | | X | | | | | X | X | X | | | | X | X | X | X | X | X | X | 11 |
| Canthium odoratum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | | | 3 |
| Capillipedium spicigerum | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Carissa ovata | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | | | X | X | | | | | 5 |
| Cascabela thevetia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | 1 |
| Cassia rotundifolia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | 2 |
| Casuarina cunninghamiana | | | | | | | | X | | | | | | | | | | | | | | | | | X | | | | | X | | | X | X | | X | 6 |
| Casuarina glauca | | X | | X | | | X | | | | | | X | | X | | | | | | | X | | | | | | | | X | | | | | | | 7 |
| Casuarina sp | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Catharanthus roseus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Ceriops tagal | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |

## Appendix 1 cont.

| Reaches | Reach 1 | | | | | | Reach 2 | | | | | | Reach 3 | | | | | | Reach 4 | | | | | | Reach 5 | | | | | | Reach 6 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1_1a | 1_1b | 1_3a | 1_3b | 1_4a | 1_4b | 2_1a | 2_1b | 2_3a | 2_3b | 2_5a | 2_5b | 3_1a | 3_1b | 3_2a | 3_2b | 3_3a | 3_3b | 4_1a | 4_1b | 4_2a | 4_2b | 4_3a | 4_3b | 5_1a | 5_1b | 5_3a | 5_3b | 5_5a | 5_5b | 6_1a | 6_1b | 6_2a | 6_2b | 6_3a | 6_3b | Total |
| Chenopodium sp | | | | | | | | | | | X | | | | | | | | | | | | X | | | | | | | | | | | | | | 2 |
| Chloris gayana | | | | | | | | | | | | | | X | | X | | | | | | | X | | | | X | | Y | | | | | | | | 5 |
| Chloris sp | | | X | | | | | X | X | X | | | | | | | | | | | X | | | X | | | | | | | | | | | | | 6 |
| Chloris virgata | | | | | | | X | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | 3 |
| Cirsonium australe | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | 1 |
| Citribatus spinescens | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Citrus sp | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | 1 |
| Clerodendrum floribundum | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | 1 |
| Coleospermus reticulatus | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Commelina diffusa | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Corymbia citriodora | X | X | X | | | | | | | | | | X | | X | | X | | | | | | | | | | | | | | | | | | | | 6 |
| Corymbia intermedia | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | X | | | X | 4 |
| Corymbia sp | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | X | | X | | 3 |
| Corymbia tessellaris | | | | | | | | X | | | | | | X | | | X | X | X | X | X | | X | X | | | | X | | | X | | X | | | X | 13 |
| Crotalaria mitchellii | | | | | | | X | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | 2 |
| Crotolaria pallide | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | X | | | | | | 2 |
| Crotolaria sp | | | | | | | | | | | | X | | | | X | | | | | | | X | X | X | | | | X | | | | | X | X | X | 9 |
| Cryptocarya triplinervis | | | | | | | | | | | | | | | | X | | | | X | | | | | | | | X | | | X | | X | | | X | 8 |
| Cryptostegia grandiflora | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | | | | X | | | | X | X | | 6 |
| Cupaniopsis anacardioides | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | X | | | | X | X | 4 |
| Cymbopogon refractus | | | | | | | | | | X | | | | | | | X | | X | | | X | | | | | | | X | | | | | | | | 5 |
| Cynodon dactylon | | | | | | X | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | 3 |
| Cyperaceae sp | | | X | | | | | | | | | | | | | | | | X | | X | | | X | | | | | | | | | | | | | 5 |
| Cyperus gigantea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Cyperus javanicus | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Cyperus rotunda | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Digitaria didactyla | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | 2 |
| Digitaria sp | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | X | | 2 |
| Diospyros fasciculosa | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | 2 |
| Diospyros geminata | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | X | X | X | | | 5 |
| Dodonaea lanceolata | | X | | | | | | | | | | | | | | | X | | | | | | | | | | | | X | | | | | | | | 3 |
| Drypetes deplanchei | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | X | | | | X | 4 |
| Dysoxylun fraserianum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | 1 |
| Dyspyros geminata | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Ehocarpus obovatus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | 1 |
| Emilia sonchifolia | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Entolasia sp | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | 1 |
| Eragrostis sp | | X | | | | | | | | X | | | | | | | | | | X | X | | | | | | | X | | X | | | | | | | 6 |
| Erythrina vespertilio | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | 1 |
| Eucalyptus crebra | X | X | X | | | X | | | | | | | X | | X | | X | | | | | X | | | | | | | X | | | | | X | | | | 10 |
| Eucalyptus sp | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | X | | | | 2 |
| Eucalyptus tereticornis | | | X | | | X | | X | | | | | | X | | X | X | | X | | X | | | X | | | X | X | X | X | X | | X | X | X | X | 18 |
| Eugenia uniflora | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | 1 |
| Euphorbia cyathocarpa | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Euroschinus falcata | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | 1 |
| Eustrephus punctatum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Excoecaria agallocha | | | | | | | X | | | | | | X | | | | X | | | X | | X | | X | | | | | | | | | | | | | 6 |
| Fabaceae sp | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Ficus coronata | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Ficus opposita | X | | | | | | X | X | X | | | | X | | | X | | X | X | X | X | X | | X | X | | X | X | | X | | X | X | | X | X | 20 |
| Ficus sp | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | | | | | | X | | 3 |
| Fimbristylis ferruginea | | X | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | 3 |
| Fimbristylis polytrichoides | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Fimbristylis sp | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | | | | | | | X | | 3 |
| Fimbristylis sp.2 | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | 1 |
| Geijera salicifolia | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 1 |
| Geijera salicifolia var latifolia | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | X | | | | X | 3 |
| Geitoplesium sp | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | 1 |
| Glochidion lobocarpum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Gomphrena celosioides | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | 1 |

## Appendix 1 cont.

| Reaches | Reach 1 | | | | | | Reach 2 | | | | | | Reach 3 | | | | | | Reach 4 | | | | | | Reach 5 | | | | | | Reach 6 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1_1a | 1_1b | 1_3a | 1_3b | 1_4a | 1_4b | 2_1a | 2_1b | 2_3a | 2_3b | 2_5a | 2_5b | 3_1a | 3_1b | 3_2a | 3_2b | 3_3a | 3_3b | 4_1a | 4_1b | 4_2a | 4_3b | 4_3a | 4_3b | 5_1a | 5_1b | 5_3a | 5_3b | 5_5a | 5_5b | 6_1a | 6_1b | 6_2a | 6_2b | 6_3a | 6_3b | Total |
| Grevillea latifolia | X | | | | | | | X | | | | | | | | | X | | | | | X | | | | | | | | | | | | | | 4 |
| Heliotropium amplexicaule | | | | | | | X | | | | | | | | | | | | X | X | X | X | | | | | | | X | | | | | | | | 6 |
| Heteropogon contortus | | | | | | | X | | X | | | | | | | | X | | | | | | X | | | | | | | | X | X | X | | | | 7 |
| Hibiscus heterophyllus | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Hyparrhenia rufa | | X | | | | | X | X | | | | | | X | X | | X | X | | | | | | | X | | | | | | | X | X | | | | 10 |
| Indigofera sp | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | 1 |
| Indigofera trifoliata | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | 2 |
| Jagera pseudophorus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Jasminum simplicifolium | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | 3 |
| Jasminum didymum | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | 2 |
| Jasminum didymum subsp racemosa | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | | X | | | | | | 3 |
| Jasminum sp | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | X | | 2 |
| Lamandra sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | 1 |
| Lantana camara | | | | | | | | | X | X | X | | | | | | | | X | X | X | | | | X | X | X | X | | X | X | X | X | X | X | X | 17 |
| Lantana montevidensis | X | X | | | | | X | X | | X | X | X | | | X | | X | X | X | X | X | X | | X | X | | X | | X | X | X | X | X | X | X | X | 25 |
| Limonium solanderi | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | 1 |
| Lomandra longifolia | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | X | X | X | | | 5 |
| Lophostemon confertus | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Lophostemon sp | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | 1 |
| Lophostemon suaveolens | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | 1 |
| Macaranga tanarius | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Macfadyena unguis-cati | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Macroptilium atropurpureum | | X | | | | | X | X | | | | | | X | | X | | X | | | | X | X | | X | | | | | | | | | | | | 9 |
| Macroptilium cathyroides | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | 1 |
| Malaisia scandens | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | X | | | | | | 2 |
| Mallotus discolour | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Mallotus philippensis | | | | | | | | | | | | | | | | | | | X | X | X | | | | | | | | X | X | X | X | X | X | X | X | 11 |
| Maytenus disperma | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | 1 |
| Melaleuca bracteata | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | | | | X | | | | | | 3 |
| Melaleuca fluviatilis | | | | | | | | | | | | | | | | | | | X | | | | | X | X | | | | | | | | | | | | 3 |
| Melaleuca leucadendra | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | | | | | | | 2 |
| Melaleuca linariifolia | | | | | | | | | | X | | | | | | | X | | | | | | | X | X | X | | | X | | | X | X | X | X | X | 11 |
| Melaleuca quinquenervia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | 1 |
| Melaleuca sp | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | | | | X | | | | 3 |
| Melia azedarach | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | | X | | | 3 |
| Melinis repens | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | X | X | | | | 4 |
| Microsproum puntulatum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Murraya paniculata | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | 1 |
| Natelaea microcarpa | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Ocna sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | 2 |
| Opuntia sp | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | X | | | | | | | 2 |
| Osbornia octodonta | | | | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| Ottochloa sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | 1 |
| Panicum maximum | | X | | | | | X | | | | | | | X | X | | | X | X | | | | | | X | X | | | X | | | | | | | X | 10 |
| Panicum maximum var coloratum | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Panicum maximum var trichoglume | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | 1 |
| Panicum sp | | | | | | | | X | X | | | | | X | | X | | | | X | X | X | | X | | | | | | | | X | X | 2 | X | | 12 |
| Paspalidium sp | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | 1 |
| Paspalum sp | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | 1 |
| Paspalum vaginatum | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | | | | | | | | | | 3 |
| Passiflora foetida | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | | | | 2 |
| Passiflora sp | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 2 |
| Passiflora suberosa | | | | | | | | | | | | | | | X | | | | | | | | | | X | | | | | | X | X | X | | X | X | 7 |
| Petalostigma pubescens | | | | | | | | | | | | | | | X | | | | | | | X | | | | | | | X | | | | | | | | 3 |
| Phragmites australis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | 1 |
| Phyllanthus sp | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | 1 |
| Pittosporum revolutum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Planchonia careya | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | | | | X | | 3 |
| Pleiogynium timorense | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | X | | | X | | 3 |
| Poacea sp | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | 1 |

## Appendix 1 cont.

| Reaches | Reach 1 | | | | | | Reach 2 | | | | | | Reach 3 | | | | | | Reach 4 | | | | | | Reach 5 | | | | | | Reach 6 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1_1a | 1_1b | 1_3a | 1_3b | 1_4a | 1_4b | 2_1a | 2_1b | 2_3a | 2_3b | 2_5a | 2_5b | 3_1a | 3_1b | 3_2a | 3_2b | 3_3a | 3_3b | 4_1a | 4_1b | 4_2a | 4_2b | 4_3a | 4_3b | 5_1a | 5_1b | 5_3a | 5_3b | 5_5a | 5_5b | 6_1a | 6_1b | 6_2a | 6_2b | 6_3a | 6_3b | Total |
| Polyscias elegans | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | 1 |
| Portulaca oleracea | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Portulaca pilosa | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | 1 |
| Protasparagus aethipicus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Pterocaulon sphacelatum | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | 1 |
| Rhizophora stylosa | X | X | X | X | X | X | X | | X | X | X | X | X | | X | X | X | | | | | | | X | | | | | | | | | | | | | | 16 |
| Rhynchosia acuminatissima | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Richinus communis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | 1 |
| Salvia coccinia | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | X | | | | | | | | 3 |
| Salvia riparia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | 1 |
| Scleria sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Scolopia braunii | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Sesbonia cannabina | | | | | | | | | | | | | | | | X | | | | | | | X | | | | | | | | | | | | | | 2 |
| Sesuvium portulacastrum | | | | X | X | X | X | X | | X | | | | X | | X | | X | X | | | | X | | | | X | X | X | | | | | | | | | 15 |
| Shoenus sp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Sida cordifolia | | | | | | | X | | | X | X | | | | | | | X | X | | X | X | | X | | | | X | | X | | | | | X | X | | 12 |
| Sida rhombifolia | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | 2 |
| Sida sp | X | | | | | | X | X | X | X | | X | X | X | X | | X | X | X | | X | | | X | | | | X | X | X | | | | | | X | | 18 |
| Sida subspicata | | | | | | | | | | | | | | | | | | | | | X | X | | X | | | | | | | | X | | | | | | 4 |
| Similax australis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Sporobolus pyramidalis | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | 1 |
| Sporobolus sp | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | 3 |
| Sporobolus virginicus | X | X | X | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | X | X | X | X | | | | | | X | | 26 |
| Stachytarpheta jamaicensis | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | 1 |
| Stephania japonica | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | 1 |
| Streblus brunonianus | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | X | | X | | X | | | | X | | 6 |
| Stylosoutles sp | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | 1 |
| Suneda australis | | X | | | | | | | X | X | X | X | | | | | | | X | X | | X | X | X | | | | | | | | | | | | | | 10 |
| Synedrellopsis grisebachii | | | | | | | | | | | | | | | | | | | X | X | X | X | | | | | X | X | | X | X | | | | X | | 9 |
| Syzgium australe | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | | | X | X | X | | | | | 4 |
| Terastigma nickens | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Terminolia porphyrom | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | 1 |
| Theneda sp | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | 1 |
| Themeda triandra | X | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | X | | X | | X | | | | | 6 |
| Thumbergia alata | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | 1 |
| Timonius timon | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | 1 |
| Tridax procumbens | | | | | | | | | | | | X | | X | | | | | | | | | | | X | | | | | X | X | | | | X | | | 6 |
| Triumfetta rhomboidea | | | | | | | | | X | | | | | | | | | | | | | | X | | X | | | | | | X | | | | X | | | 4 |
| Trophis scandens | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | 1 |
| Trophis sp | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | 1 |
| Turrgea brownii | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | 1 |
| undientified weed 1 | | | | | | | | | | | X | | | | | | | X | | | | | | | | | | | | | | | | X | | | | 3 |
| unidentified weed 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | 1 |
| unidentified weed 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | 1 |
| unidentified grass 1 | | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | | X | | | | | | | 3 |
| unidentified grass 2 | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| unidentified shrub 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | 2 |
| unidentified shrub 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | 1 |
| unidentified shrub 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | 1 |
| unidentified shrub 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | 1 |
| unidentified tree 1 | | X | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | | | X | | X | | X | | 6 |
| unidentified tree 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | 2 |
| unidentified vine 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | X | | 3 |
| unidentified vine 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | 1 |
| Vitex trifiora | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | 1 |
| Waterhousia florabunda | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | X | | | | | | 3 |
| Species richness | 17 | 19 | 10 | 6 | 5 | 11 | 21 | 20 | 16 | 20 | 15 | 10 | 14 | 17 | 15 | 17 | 24 | 15 | 39 | 24 | 26 | 27 | 24 | 25 | 41 | 10 | 18 | 20 | 19 | 32 | 44 | 50 | 29 | 32 | 53 | 34 | |

Appendix 2: Structural components (height and % cover) of zones at 36 riparian monitoring sites within six reaches on the Boyne River in 2002 and 2004 (refer to CD Appendices).

Appendix 3: Transect maps for 36 riparian monitoring sites within six reaches on the Boyne River in 2002 and 2004 (refer to CD Appendices).