Regulation of River Flow and Aquatic Ecosystem Health of the Barron Gorge, FNQ

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Abstract

Flow of water to the upper reaches of the Barron River and for Barron Gorge Hydroelectric Power Station (Power Station) operations have been regulated by the operation of Tinaroo Dam since 1958. Flow in the lower reaches including the waters which flow over the Barron Falls, through the Barron Gorge, and to the coastal plain reaches of the Barron River have been regulated by the operation of the Power Station since 1963.

Water is diverted to the Power Station from the Barron River at Kuranda Weir (approximately 900 m upstream from Barron Falls), and returned to the river below the hydroelectric station approximately 3 km downstream of Kuranda Weir. To maintain the connectivity and health of aquatic communities in the diverted section of the Barron River (Barron Gorge), Stanwell Corporation Limited (Stanwell) have released water from the weir to Barron Falls in accordance with the *Barron River Resource Operation Plan* (ROP) since 2004. frc environmental assessed the likely impact of the initially proposed ROP environmental release and Power Station operations on the ecosystem health of the Barron Gorge in 2004; and have assessed the adequacy of the current release in maintaining aquatic ecosystem health and connectivity in the Barron Gorge since.

An array of locations, above, within, and below Barron Gorge were surveyed in 2004, 2005, and 2007. Water quality, in-stream habitat, riparian and aquatic flora, macro-invertebrate and fish communities were surveyed. To detect changes in aquatic community structure, data was analysed using a range of indices and multivariate analyses. Monitoring to date has focused on the assessment of ecological health, and indicates that there has been no significant change as a result of the environmental flow currently released from Kuranda Weir by Stanwell.

Stanwell is committed to better understanding the environment in which it operates and is looking at ways to improve future monitoring to more quantitatively assess changes in the aquatic environment and in aquatic floral and faunal community structure, aquatic ecosystem functioning and health in response to its operations, including varied / reduced flow regime and the key ecological flow requirements of the ROP.

Introduction

Flow in the lower reaches including the waters which flow over the Barron Falls, through the Barron Gorge, and to the coastal plain reaches of the Barron River is regulated by the operation of the Barron Gorge Hydroelectric Power Station (Power Station). The Power Station was commissioned in 1963, and is owned and operated by Stanwell; it has a maximum capacity of 66 MW which is bid into the National Electricity Market (Stanwell Corporation Limited 2006). The Power Station is located 20 km north-west of Cairns, Qld within the Barron Gorge. Water is diverted to the Power Station from the Barron River at Kuranda Weir, which is located approximately 900 m upstream of Barron Falls, and returned to the river immediately below the Power Station approximately 2 km downstream of Barron Falls. The generation of power is dependant on water availability and responds to meet peak electricity demand; as a result the discharge of water from the Power Station to the river downstream is not continuous or regular.

In addition to Kuranda Weir, flow in the Barron River is regulated by the influence of a number of other major obstructions. The Barron River has a total catchment area of approximately 1,900 km^2; its source is in the Mount Hypipamee National Park, at an elevation of 900 m. Flow is first restricted by the Tinaroo Dam, which is located in the Atherton Tablelands approximately 20 km downstream of the source, and later by a series of falls (Barron Falls, Lower Barron Falls, and the falls above Devils Pool) within the Barron Gorge National Park. During the wet season, Kuranda Weir is commonly overtopped by flood flows: at this time the abstraction of water for power generation has little influence on flows in the diverted section of the Barron River. However, abstraction can reduce the volume and frequency of flow to this section of the river in drier periods. At such times, the unregulated inflows of small tributaries between Barron Falls and the Power Station may have a significant influence on flow and water quality in the Barron Gorge.

In response to the release of the draft Resource Operation Plan (ROP) in 2004 (which called for 10% of river flows in the dry season to be released from Kuranda Weir), Stanwell commissioned frc environmental to conduct an assessment of the likely impacts/benefits of the proposed 10% release on the health and connectivity of aquatic communities in the Barron Gorge. This study determined that operation of the Power Station was not having a measureable impact on water quality within the river, and that the aquatic ecosystem within the Barron Gorge was healthy and diverse. In fact, the presence of both off-stream and on-stream habitats due to the dry season flow regime contributed to aquatic biodiversity within the gorge. Furthermore, release trials indicated that an increase in flows released from Kuranda Weir was unlikely to have a significant impact (positive or negative) on aquatic ecosystems.

The findings and recommendations of this 2004 study (frc environmental 2004a) were incorporated into the final *Barron River Resource Operation Plan* (the ROP) (DNRM 2005), which prescribes the release of 70 ML of water / week from the weir (rather than a percentage of river flows). This release aims to maintain the ecological connectivity and health of aquatic communities in the diverted section of the Barron Gorge, while recognising that the restoration of a more ‘natural’ flow is not necessarily desirable, due to the ecological adjustments that have occurred over the past four decades, and the potential for detriment to existing ecosystems inherent in further change.

Stanwell manage the release of the prescribed environmental flow from Kuranda Weir. To assess the adequacy of the release in maintaining aquatic ecosystem health and connectivity in the Barron Gorge, frc environmental have monitored the aquatic communities of the gorge since 2004 (see frc environmental 2004b, 2005 & 2007). This paper discusses the results of this monitoring program, and proposes considerations for future monitoring.

Methods

Study Area

Monitoring has focused on the middle reaches of the Barron River, from approximately 14 km upstream of Kuranda Weir, to approximately 2 km downstream of the Power Station. Water quality, in-stream habitat, riparian and aquatic flora, macro-invertebrate and fish communities have been assessed to provide an indication of ecosystem health in stream segments that lie above, within, and below the Barron Gorge, since 2004 (Figure 1). Twenty sites were surveyed in September 2004 and July 2005, to provide an understanding of the spatial variability of aquatic communities in the study area (Figure 1) (frc environmental 2004b & 2005). A subset of twelve sites was surveyed in August 2007; these sites were selected based on the results of previous surveys, to provide a representative cross section of habitats within the study area (frc environmental 2007). Both on-stream and off-stream habitats were sampled where they were present.

Habitat

During each survey event, at each site, in-stream habitat was described using the Australian River Assessment System (AusRivAS) physical assessment protocols (DNRM 2001a); the width and composition of the riparian zone was described; aquatic macrophytes were identified; and the presence of exotic species was recorded.

Water Quality

During each survey event, at each site, physical water quality parameters were recorded using a TPS 90 FLT water quality meter. Water quality data was compared to the Queensland Water Quality Guidelines (QWQG) for Upland Streams in the Wet Tropics Region (EPA 2006) and Australian New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australian and New Zealand (ANZECC & ARMCANZ 2000) default trigger values for Lowland Rivers of Tropical Australia.

Macro-invertebrates

At each site, macro-invertebrates were sampled and described in accordance with AusRivAS protocols (DNRM 2001a). Samples were collected from the substrate of pools and runs; the substrate of riffle zones; and from amongst fringing and trailing bank vegetation. To describe communities, and to provide for a comparative indication of stream health, family richness, diversity, the number of Plecoptera (stoneflies), Ephemoptera (mayflies), and Trichoptera (i.e. the PET richness), and the Stream Invertebrate Grade Number Average Level Index (i.e. the SIGNAL 2 Index) (Chessman 2003) were calculated for each site and habitat type. SIGNAL 2 / Family Bi-plots were developed to provide an indication of the physical and chemical factors affecting the macro-invertebrate communities (Chessman 2001 & 2003). Community and habitat data from each site and habitat sampled were also analysed with the AusRivAS predictive model for Queensland coastal habitats sampled in spring (see Coysh et al. 2000).

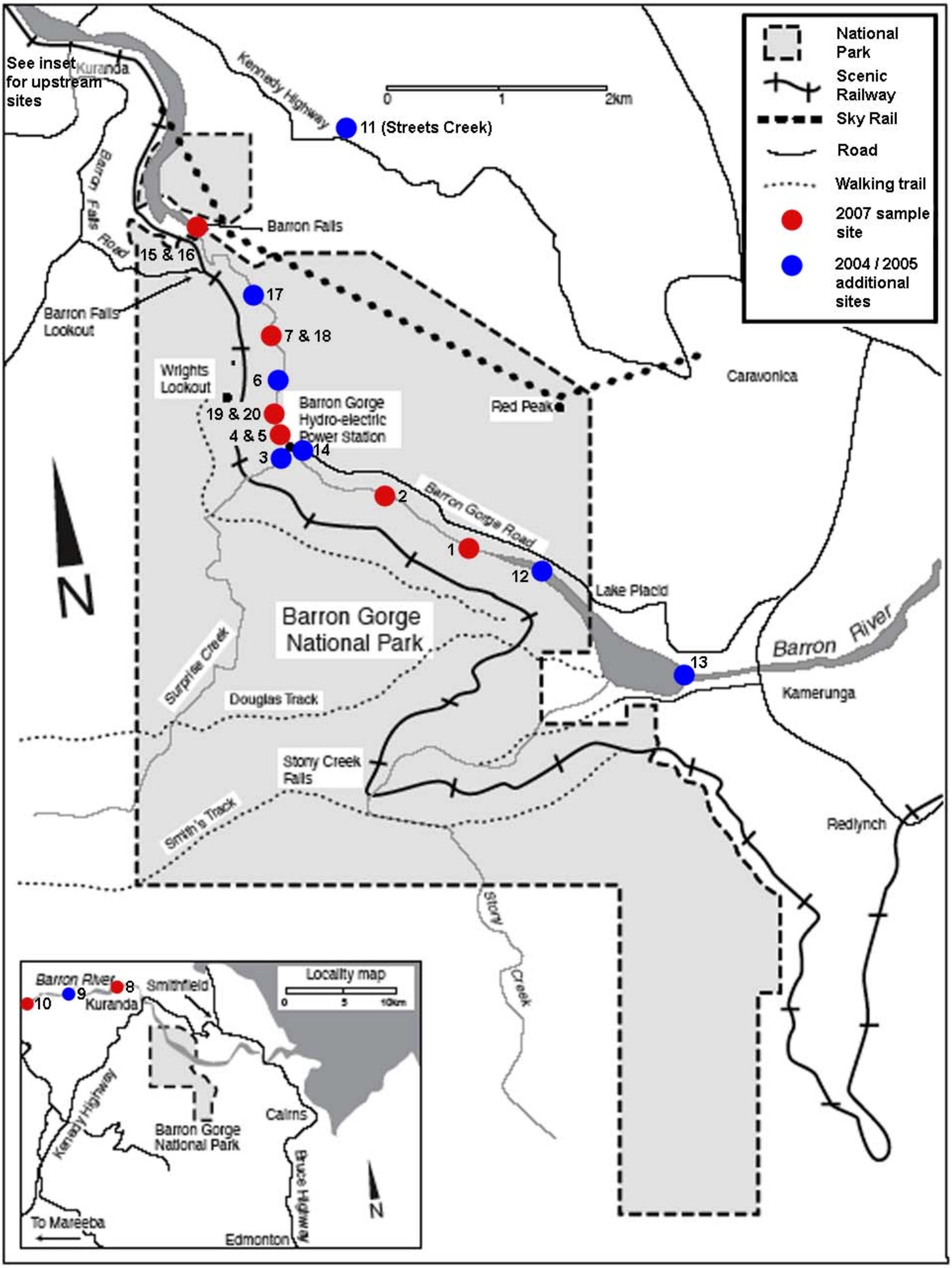

Figure 1 Study area showing the approximate location of all study sites (2004 to 2007)(adapted from Department of Environment 1998).

A Bray-Curtis similarity coefficient was calculated on fourth-root transformed data for all samples taken within each stream segment, and a similarity matrix was generated. To examine differences among macro-invertebrate assemblages between sampling events and stream segments, the matrix was analysed using one-way analysis of similarities (ANOSIM). Separate analyses were done for each of the habitats sampled, as habitat type (e.g. bed, riffle and edge) is strongly linked with macro-invertebrate community richness, composition and abundance. The relationships between communities in different stream segments were displayed visually using non-metric multidimensional scaling (MDS). To determine which taxonomic groups were responsible for differences in assemblages between years at each location, community data were analysed using SIMPER (similarity percentages – species contributions) (Clarke 1993).

Fish

At each site, fish were sampled using a combination of methods, which included: backpack electrofishing (Smith-Root LR-24), in-water visual census, and by setting at least three baited traps of 1.5 mm mesh at each site, which were allowed to soak for a minimum of 4 hrs. Where conditions permitted, backpack electrofishing was applied evenly across each habitat type throughout the channel. The voltage was adjusted according to changes in conductivity. Species were identified and counted in the field. Sampling was conducted under General Fisheries Permit No. 54790 and Animal Ethics Approval No. CA 2006/03/106. To describe communities, and to provide for a comparative indication of stream health, species richness, the proportion of exotic fish and the number of vulnerable and endangered fish were determined for each site.

Results and Discussion

The aquatic ecology studies indicate that the aquatic ecosystem health of the Barron Gorge is in good condition. Since commencing monitoring in September 2004, no major changes to in-stream habitat, riparian vegetation, aquatic macrophytes, aquatic macroinvertebrate communities or fish communities of the gorge have been detected. Aquatic communities reported in this monitoring program are broadly similar to those recorded in previous studies in the Barron River sub-catchment (see Russell et al. 2000; Choy et al. 1999; Pusey & Kennard 1994).

Habitat

Few of the in-stream habitats in the study area have been disturbed (Russell et al. 2000). Available habitat for use by macro-invertebrate and fish fauna varies greatly between stream reaches. Observations during surveys indicate that the in-stream, habitats remained similar throughout monitoring events.

Within the study area, riparian vegetation is typical of rainforest and eucalypt wet sclerophyll communities. Riparian vegetation of the Barron River is largely intact, though roads and other infrastructure fragment the riparian continuity in places. Previous studies found that much of the riparian vegetation in the catchment is relatively intact (including many areas outside of the World Heritage Area), classifying 60% of sites as undisturbed or having only minor disturbance (Russell et al. 2000). Sites within the present study area typically fall within these categories, with riparian vegetation observations being similar between monitoring events.

Several weeds in the disturbed areas of the riparian zone throughout the study area have been detected during surveys. Where the riparian vegetation has been disturbed, Singapore daisy (*Sphagneticola trilobata*) is common in the Barron Gorge and throughout the entire Barron Catchment (pers. comm. Luke Johnston). Lantana (*Lantana camara*), guinea grass (*Panicum* *maximum*), wild tobacco (*Solanum mauritianum*), purple top (*Verbena bonariensis*) and Sicklepod (*Senna* sp.) are also common upstream of Barron Falls and throughout the entire Barron Catchment where the riparian vegetation has been disturbed (pers. comm. Luke Johnston).

Monitoring has recorded no endangered, vulnerable, or rare aquatic macrophytes in the Barron Gorge.

Water Quality

Studies indicate that water quality within the study area was mostly within the applied guidelines. However, levels of daytime Dissolved Oxygen (DO) were above the range specified in the QWQG but were within ANZECC & ARMCANZ (2000) guidelines in August 2007 and 2004 (Figure 2).

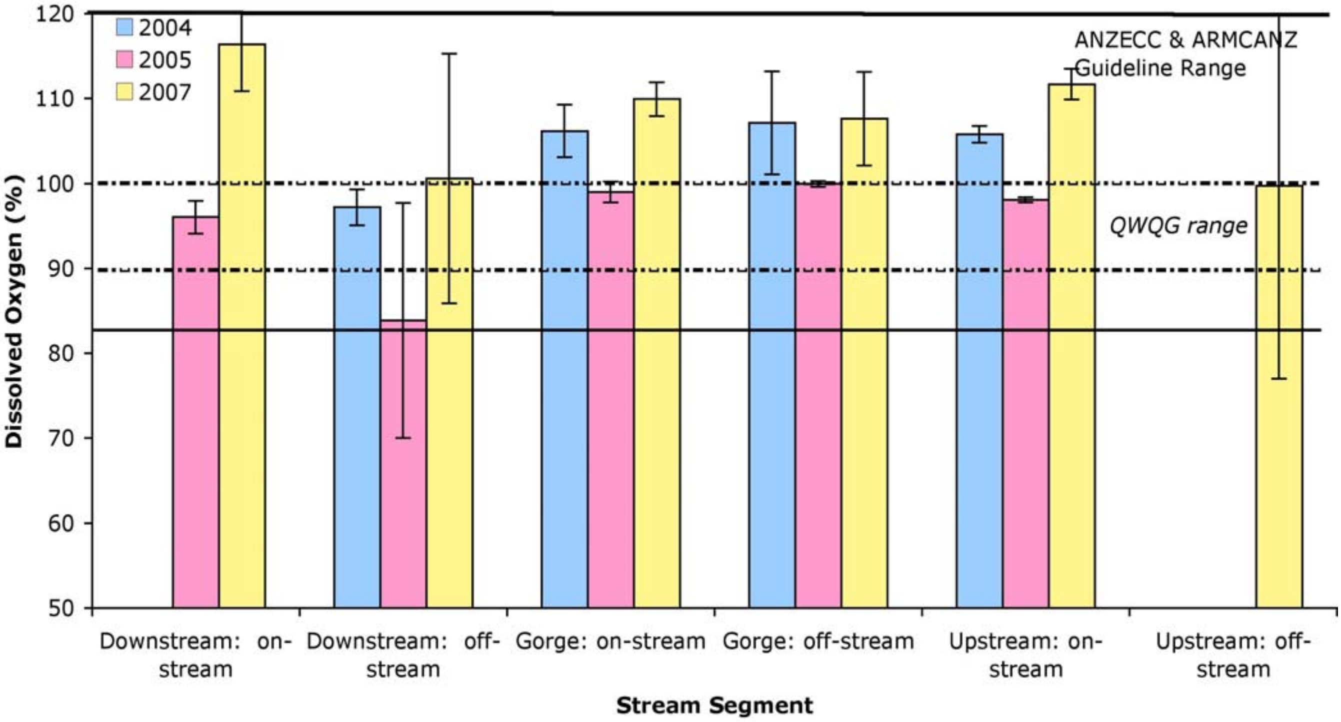

Figure 2 Mean dissolved oxygen concentration in each segment of the Barron River surveyed in: September 2004, July 2005 and August 2007(+/- SE).

Macro-invertebrates

Within each segment of the Barron River, the richness, diversity, PET richness and SIGNAL 2 index of macro-invertebrate communities have fluctuated over time, highlighting the relatively high natural temporal variability of communities within the study area. However, such fluctuations in index values between monitoring events were not substantial when compared with the spatial variability (e.g. note the relatively large error bars for PET richness, Figure 3). There were no obvious trends of decreasing ecosystem health over time, and fluctuations are within the range of expected inter-annual variation, and not indicative of a decline in ecosystem health.

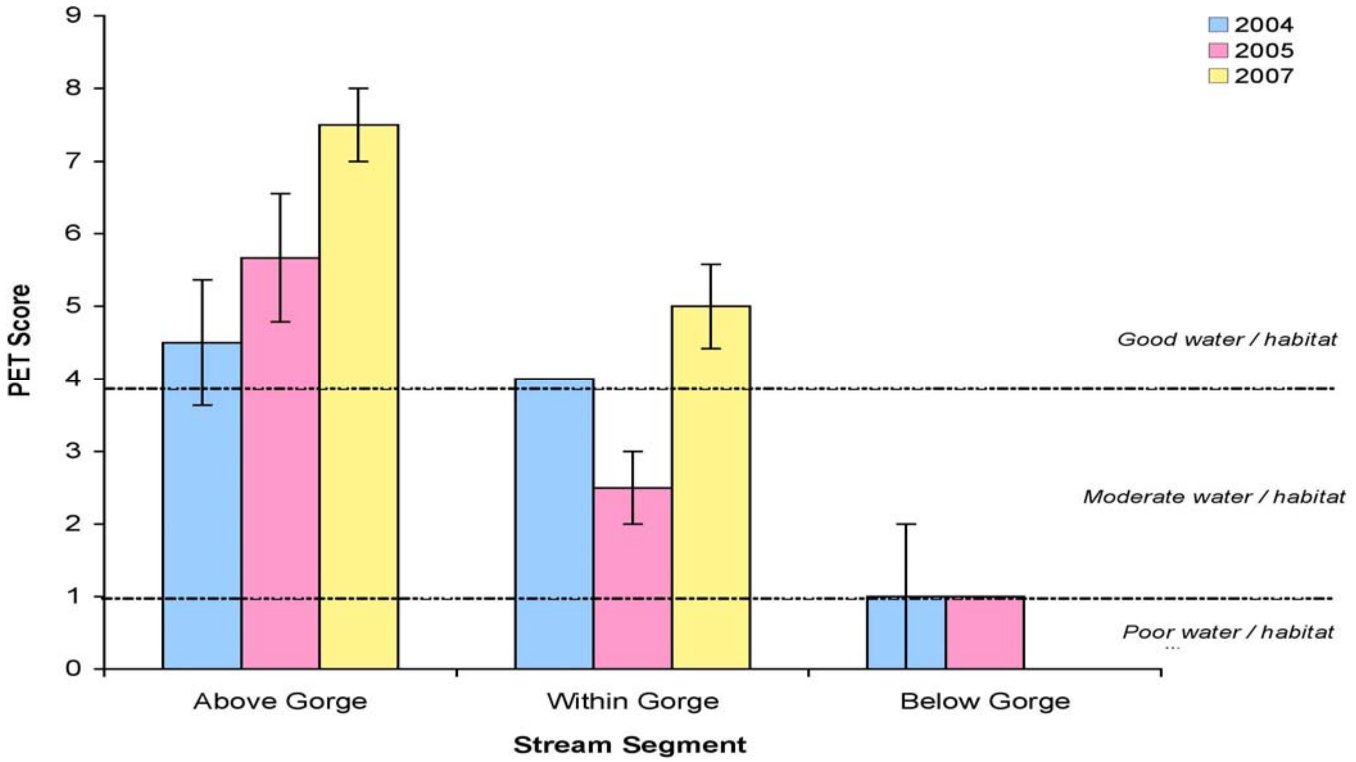

Figure 3 Mean PET richness for macro-invertebrate communities in riffle habitats in each segment of the Barron River surveyed in: September 2004, July 2005 and August 2007.

Overall, macro-invertebrate community structure has differed somewhat between years in each habitat in each segment of the Barron River (e.g. Figure 4, ANOSIM), with differences between sampling events being primarily attributed to changes in the presence of a few beetle, bug, fly and shrimp families (SIMPER). These differences in composition were not large, nor were they consistent across sites within stream segments, and therefore are likely to reflect annual variation in biological processes (such as the timing of egg deposition, hatching or recruitment) rather than an impact due to flow regulation.

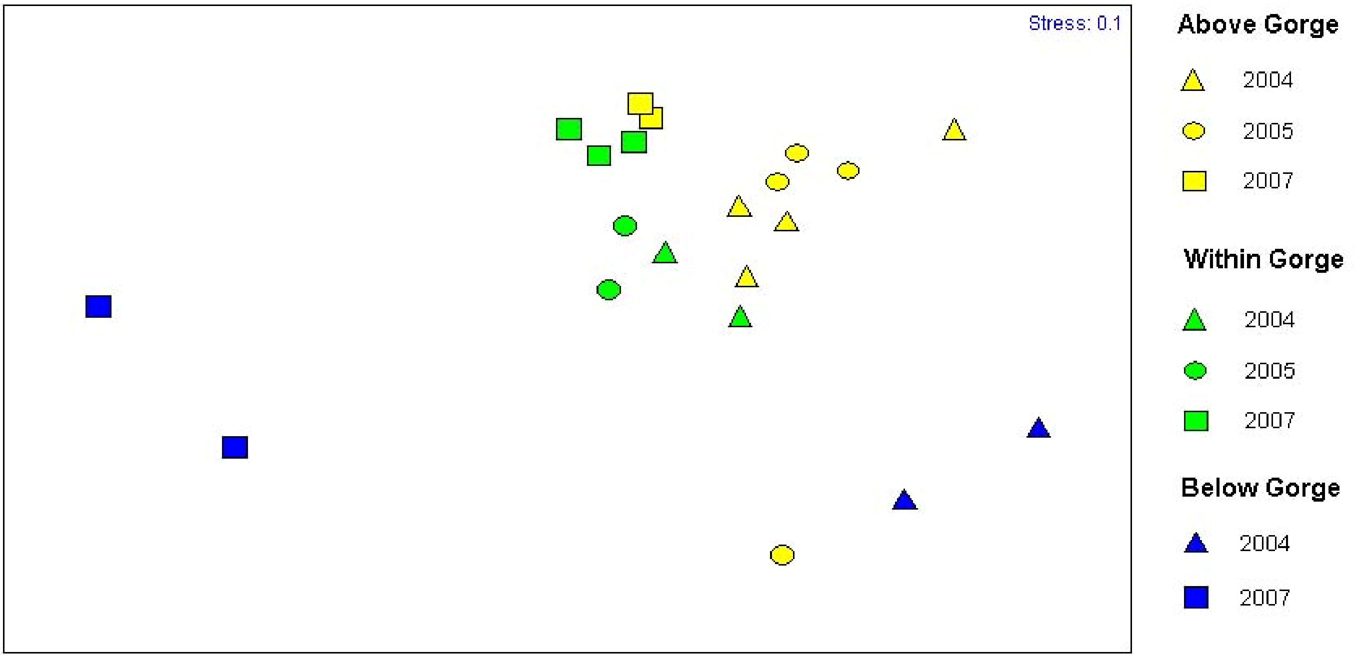

Figure 4 MDS ordination comparing macro-invertebrate communities present in riffle habitats in each segment of the Barron River surveyed in: September 2004, July 2005 and August 2007.

Macro-invertebrate communities above Barron Falls generally appear to be in better condition than those below the falls, with downstream communities likely reflective of the: harsh natural physical conditions; low habitat diversity; and naturally intermittent flow regime, in the Barron Gorge (for example: see the SIGNAL 2 / Family Bi-plot for bed habitats, Figure 5).

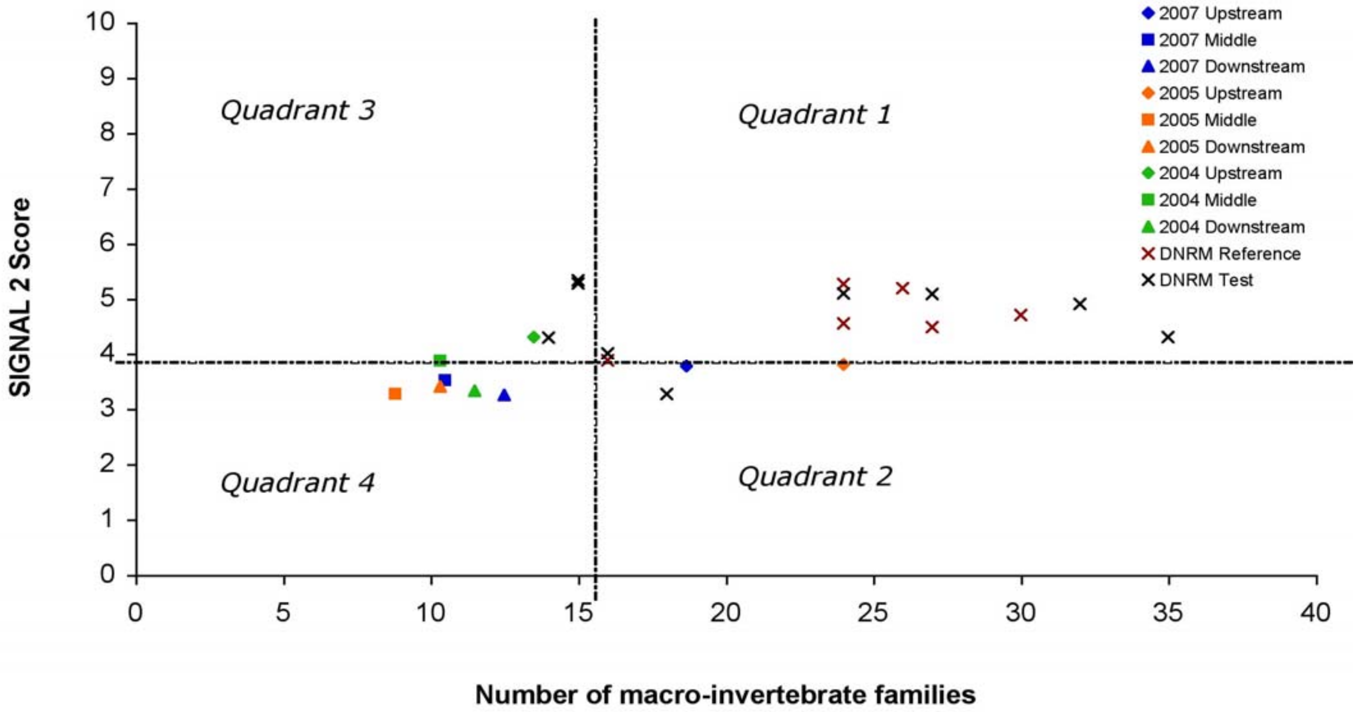

Figure 5 SIGNAL 2 / Family Bi-plot of macro-invertebrate communities sampled in bed habitats in each segment of the Barron River surveyed in: September 2004, July 2005 & August 2007, and in studies undertaken by the DNRM (Data Courtesy of the Department of Natural Resources, Mines & Energy).

Fish

The relative composition and abundance of fish communities within each segment of the Barron River is largely controlled by the life history requirements of the species involved. Many Australian fishes need to move along waterways throughout their lifecycles; fish move to: access new food supplies and different habitats; return upstream after floods; or to repopulate areas following drought. The adults of many species need to migrate between fresh and estuarine waters to breed, whilst many juvenile fish often migrate upstream to disperse and colonise new habitat. The Barron Falls is a major barrier to fish passage and profoundly influences the composition of communities in waters upstream and downstream of the falls.

Communities upstream of the upper gorge are relatively species poor (see DNRM 2001b), but support species that are indicative of good water quality, such as fly-speckled hardyheads (*Craterocephalus stercusmuscarum*). Surveys indicate communities within the Barron Gorge, between Barron Falls and lower Barron Falls, are relatively depauperate (compared to communities upstream of the falls; and between Lower Barron Falls and the Power Station), reflecting both the natural lack of longitudinal connectivity in this section of the river and the physical harshness of these waters. This lack of connectivity in the Barron Gorge results from the influence of major natural obstructions to flow, such as the upper and lower Barron Falls, and the falls immediately upstream of Devils Pool. Species present in this section of the river, such as sooty grunter (*Hephaestus fuliginosus*), share a common ability to forage on a range of prey items, which is likely to be an important factor in maintaining populations between flood events. Surveys indicate communities immediately below the Power Station are low in species richness, though this is likely to be an artefact of surveying deep, fast moving waterways, rather than indicative of an impoverished fish community.

Within each segment of the Barron River, the number of fish species caught has fluctuated over time (Figure 6). Differences likely relate to the transient presence of highly mobile species, such as bony bream (*Nematalosa erebri*) in upstream waters, rather than an actual change in composition of communities over time. Differences in fishing effort between years is likely to have also influenced the richness and abundance of species recorded. Monitoring has recorded no endangered, vulnerable, rare or exotic fish.

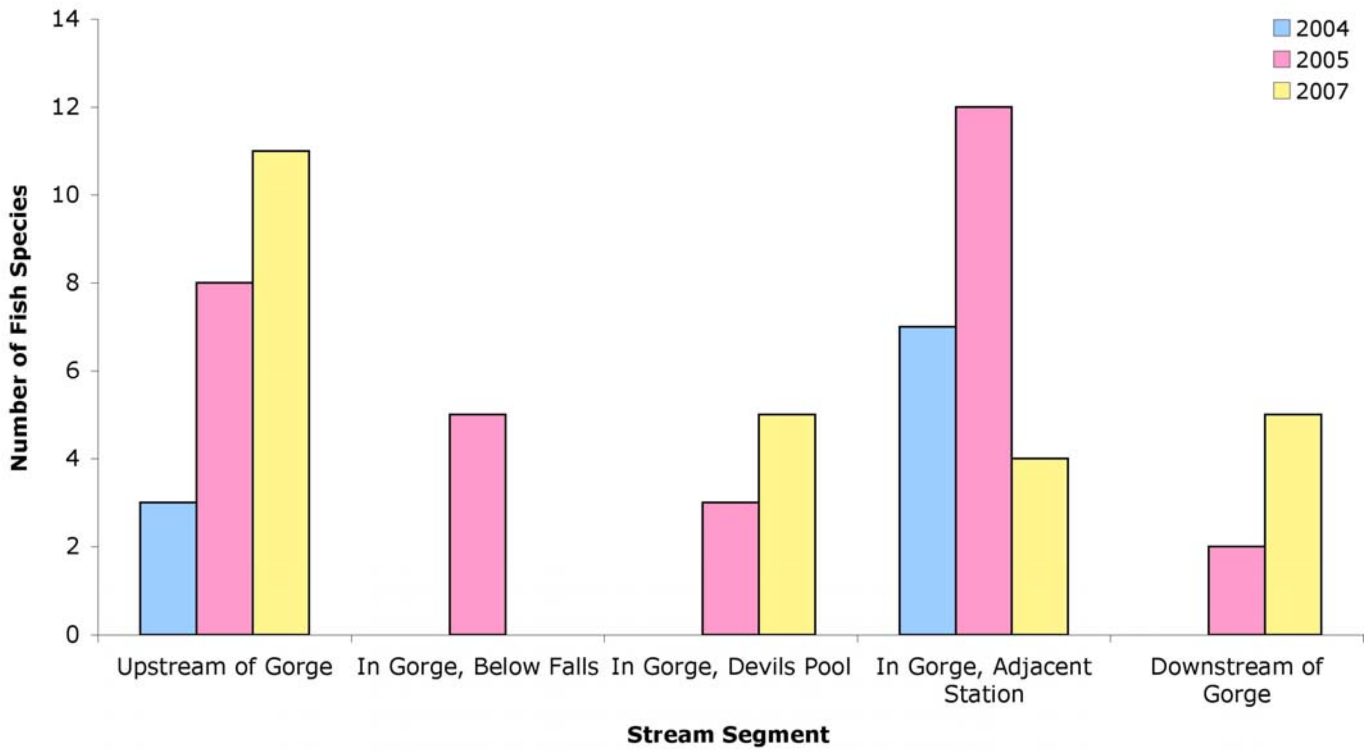

Figure 6 Number of fish species recorded in each segment of the Barron River surveyed in: September 2004, July 2005 and August 2007.
n.b. In gorge, below falls and In Gorge, Devils Pool were not sampled in 2004.

Conclusions

The current monitoring program is designed to assess aquatic ecosystem health in reaches of the Barron River above, within, and below the gorge. However, it is not adequate to quantitatively assess the relationships between flow characteristics, hydraulic and ecological connectivity, and ecosystem health. To date, monitoring indicates that the prescribed environmental release of 70 ML of water / week from Kuranda Weir has resulted in no significant change, positive or negative, on aquatic ecosystem health in the gorge. It is possible that a reduction in the flow released from Kuranda Weir may also be adequate to maintain the health of aquatic communities in the Barron Gorge, as prior to 2004 the lower gorge aquatic environment was maintained under the hydro-modified low flow regime. In order to more accurately assess changes in communities over time, future monitoring may include a quantitative survey program. Multivariate data analyses may be used to try to determine the influence of a range of environmental factors, including flow on aquatic ecology.

Incorporating flow monitoring during normal operations and maintenance activities of the weir (where flows from the weir may be reduced or cease) in conjunction with the monitoring described above is likely to provide a mechanism to further refine our understanding of the relationship between flow characteristics, hydraulic and ecological connectivity, and ecosystem health. It is also likely to enable the refinement of the monitoring program and the identification of ‘key indicators’. Future targeted, time integrated, and temporally replicated monitoring of prescribed ‘indicator’ species can support the adaptive management of the weir, and allow for a greater understanding of the critical linkages between flow and aquatic ecosystem health.

References

ANZECC & ARMCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand.

Chessman, B. 2001, *Signal 2 A Scoring System for Macro-Invertebrates ('water-bugs') in Australian Rivers*, User Manual Version, 2nd November 2001.

Chessman, B. 2003, *Signal 2 A Scoring System for Macro-Invertebrates ('water-bugs') in Australian Rivers*, User Manual Version 4, September 2003.

Choy, S. C., Marshall, C. & Marshall, J. 1999, *An Assessment of the Ecological Condition of the Barron River using Macroinvertebrates as Bioindicators*, Freshwater Biological Monitoring Program Report No. 14 (Draft), Water Monitoring Group, Department of Natural Resources.

Clarke, K. R. 1993, 'Non-parametric multivariate analysis of changes in community structure', *Australian Journal of Ecology*, 18: 117-143.

Coysh, J., Nichols, S., Ranson, G., Simpson, J., Norris, R., Barmuta, L. & Chessman, B. 2000, *AUSRIVAS Macroinvertebrate Bioassessment Predictive Modelling Manual*, CRC for Freshwater Ecology, Canberra.

Department of Environment 1998, *Visitor Information, Barron Gorge National Park*, Department of Environment, Cairns.

DNRM 2001a, *Queensland Australian River Assessment System (AusRivAS) Sampling and Processing Manual*, August 2001, Queensland Department of Natural Resources and Mines, Rocklea.

DNRM 2001b, *Condition and Trend Report*, Barron Water Resource Plan, report prepared by the Water Planning Group, Department of Natural Resources and Mines.

DNRM 2005, *Barron Resource Operation Plan*, Department of Natural Resources and Mines, Brisbane.

EPA 2006, *Queensland Water Quality Guidelines 2005*, Environmental Protection Agency, Brisbane.

frc environmental 2004a, *Review of the Draft Barron River Resource Operations Plant – Aquatic Ecology*, report prepared for Stanwell Corporation Limited.

frc environmental 2004b, *Aquatic Ecology of the Barron River: Kowrowa to Lake Placid*, report prepared for Stanwell Corporation Limited.

frc environmental 2005, *Barron River: Ecological Health Monitoring*, report prepared for Stanwell Corporation Limited.

frc environmental 2007, *Barron River: Ecological Health Monitoring*, report prepared for Stanwell Corporation Limited.

Pusey, B. J. & Kennard, M. J. 1994, *The freshwater fish fauna of the Wet Tropics Region of northern Queensland*, unpublished report.

Russell, D. J., McDougall, A. J., Ryan, T. J., Kistle, S. E., Aland, G., Cogle, A. L. & Langford, P. A. 2000, *Natural Resources of the Barron River Catchment 1. Stream Habitat, Fisheries Resources and Biological Indicators*, Information Series QI00032, Department of Primary Industries, Brisbane.

Stanwell Corporation Limited 2006, *Barron Gorge Hydro: Fact Sheet October 2006*, Stanwell Corporation Limited.

Zar, J. H. 1996, *Biostatistical Analysis*, Prentice Hall International, USA.