

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

The role of cease-to-pump rules in protecting macroinvertebrates in riffles and runs in the Gwydir Unregulated Rivers Water Sharing Plan

Project details

The *Water Sharing Plan for the Gwydir Unregulated Water Sources 2012* (DPIE Water 2012) has objectives to protect and enhance water dependent ecosystems. Flow dependent macroinvertebrate communities live in fast flowing rocky or shallow parts of a stream, known as riffle habitats. These communities are listed in the plan as one of the target populations to protect.

We use flow dependent macroinvertebrate communities in riffle habitats as indicators of river health as they are extremely responsive to hydrological changes (Monk et al. 2006). They also provide an important food resource for aquatic and terrestrial animals alike. For these reasons, macroinvertebrates have been included as a target ecological population to protect or enhance in the Gwydir unregulated water sources (DPIE Water 2012). By understanding how macroinvertebrate communities are responding to implemented WSP rules we can determine the appropriateness those rules in achieving WSP objectives.

In order to protect a proportion of low flows for the benefit of the environment, the plan imposes water access restrictions on days when flows are low. This is achieved by establishing 'cease-to-pump' (CtP) rules that require users to stop taking water when flow declines below a set level. Some rules protect a measured flow rate (gauge-based CtP) while others restrict water take once flow stops (no visible flow CtP). This project aimed to:

1. identify how macroinvertebrate communities in flowing riffle habitats recovered after a natural drying event; and
2. evaluate whether CtP rules in Halls Creek, Myall Creek, Rocky Creek and the Horton River (Figure 1) provide adequate protection for low flow macroinvertebrate communities.

Why did we need this study?

The Gwydir risk assessment identified four unregulated water sources as having a potentially high risk to macroinvertebrate communities because of water extraction under low flow conditions. These water sources are Halls Creek, Myall Creek, Rocky Creek and the Horton River.

There are objectives in each unregulated WSP that relate to flow dependent macroinvertebrate communities and their protection and enhancement. Therefore, results from this study will be used to assess the effectiveness of water sharing rules in protecting macroinvertebrates in many other water resource plans areas.

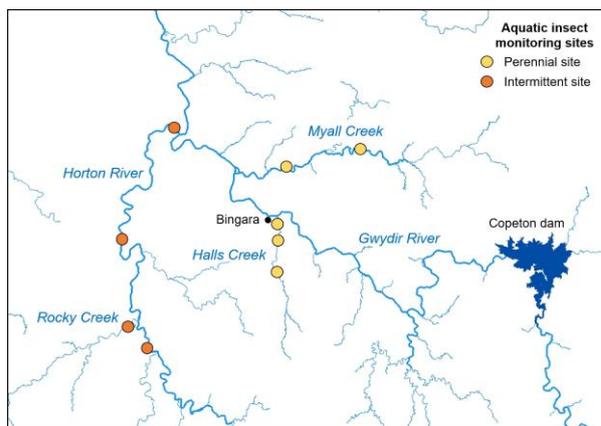


Figure 1. Project sites in the Gwydir valley.

What did we do?

Nine riffle habitat monitoring sites were established across Halls Creek, Myall Creek, Rocky Creek and the Horton River (Figure 1). Macroinvertebrates were sampled at each site 12 times between 2016 and 2018 and identified to genus level. Four of these sites experienced a no visible flow period (intermittent streams, e.g. Figure 7) for at least 100 days whilst five remained permanently flowing (perennial: e.g. Halls Creek). We tracked the recovery of macroinvertebrates at sites which dried and

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

compared this to sites which did not. The methods are described in Appendix A.

Recovery of macroinvertebrates after a no visible flow period

We found that it can take from 300-450 days for macroinvertebrate diversity in dried sites to recover to the average diversity of nearby perennial sites which did not dry (Figure 2). The macroinvertebrate diversity included up to 80 different genera at the perennial sites but only 57 at intermittent sites.

Eight of the most common macroinvertebrates recovered at different rates. Blackflies (genus *Austrosimulium* and *Simulium*), midges (*Chironominae*) and stress tolerant mayflies

(*Tasmanocoenis* and *Jappa*) rapidly recolonised to high densities within 50-100 days after drying. Other taxa like the caddisfly larvae (*Cheumatopsyche*) and baetidae mayflies (*Offadens*) had much slower recolonisation.

The *Cheumatopsyche* can take more than a year and the *Offadens* mayfly at least 200 days to recover to similar abundances as nearby perennial streams (Figure 3). Total macroinvertebrate abundance can bounce back in 150 days compared to nearby perennial streams (Figure 3). The majority of this abundance is composed of early colonisers like blackflies. Figure 4 provides a comparison of abundance recovery rates by rapid and slower colonisers at intermittent sites compared to perennial sites.

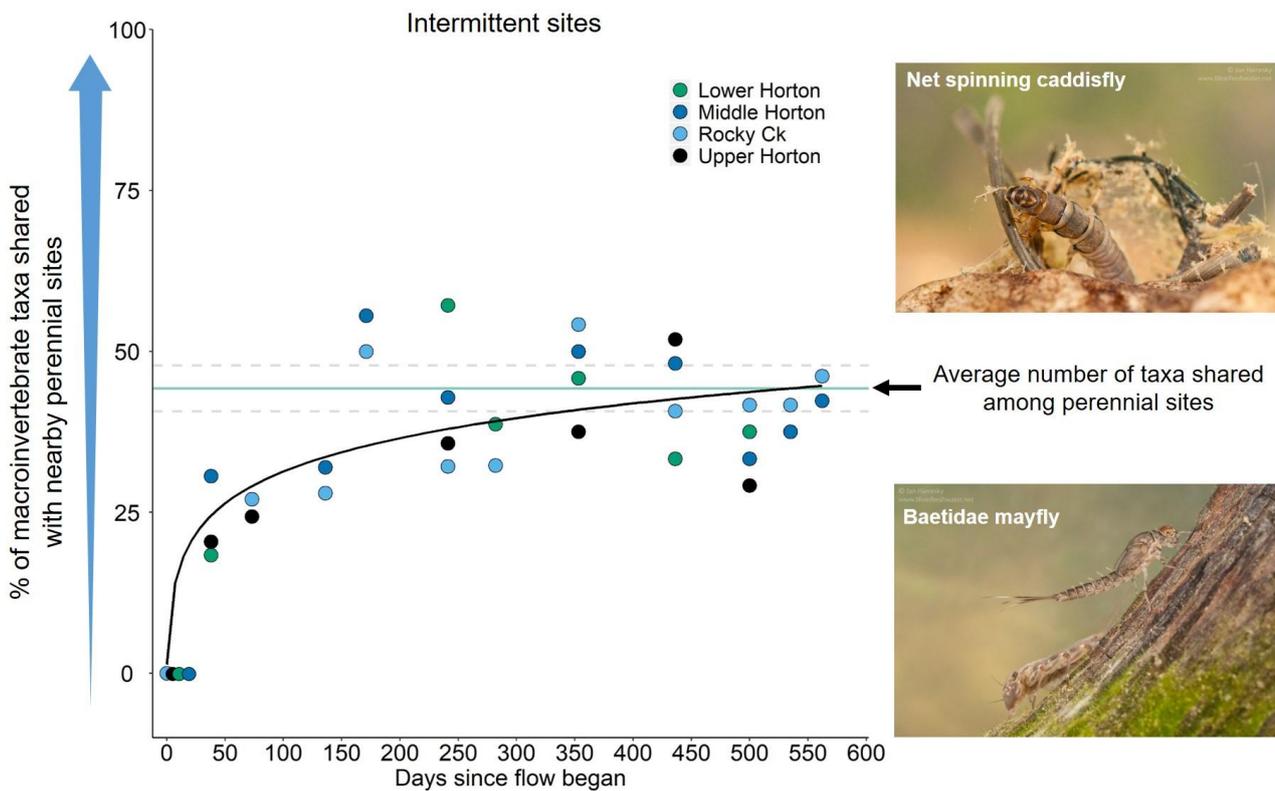


Figure 2. Recovery of macroinvertebrate diversity after a dry period in Horton River and Rocky Creek. The black fitted line is a non-linear least squares smoothing function. The green solid line represents the average % of taxa shared among perennial sites \pm 95% confidence intervals (grey dashed lines). Photos: Jan Hamrsky.

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

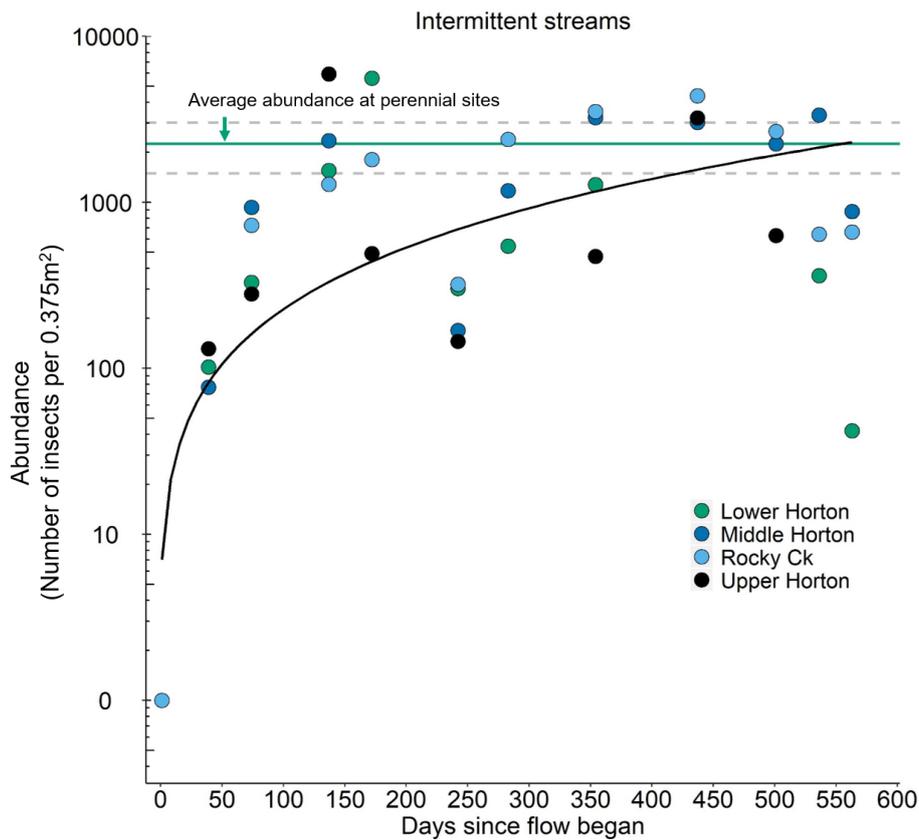


Figure 3. Recovery of total macroinvertebrate abundance for all taxa after a dry period compared to the average abundance at the perennial sites in this study. The green solid line represents the average abundance for each taxa at the perennial sites \pm 95% confidence intervals (grey dashed lines).

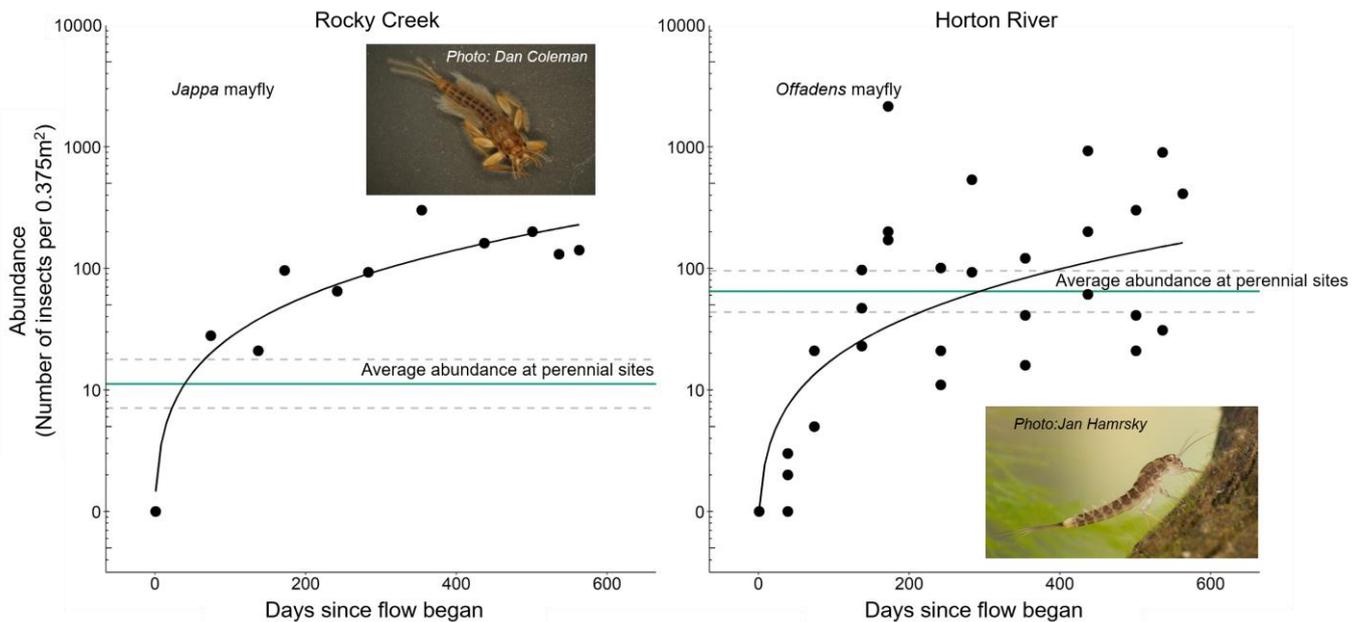


Figure 4. Examples of the recovery of taxa-specific abundance after a dry period for a rapid coloniser (*Jappa*) and a slower coloniser (*Offadens*) compared to the average abundance at the perennial sites in this study. The green solid line represents the average abundance for each taxa at the perennial sites \pm 95% confidence intervals (grey dashed lines).

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Hydrology and cease-to-pump triggers for the study streams

Halls Creek, Myall Creek, and the Horton River (including Rocky Creek) are three key tributaries of the Gwydir Regulated River. The plan protects low flow inflows to the regulated river through CtP rules. The hydrology of Halls Creek, Myall Creek and the Horton River varies not only between streams, but also on a longitudinal gradient within each stream; thus allowing the interpretation of stream sections as either perennial or intermittent for the purpose of this study.

Flow rarely stops in Halls Creek even though it has a relatively small catchment (184 km²). Only 17 days of zero flows were recorded in the entire discharge record (December 1978 – March 2018) compared to 4,762 in the upper Horton River. Halls Creek appears to be a gaining stream with baseflow during dry periods likely to be sourced from alluvial groundwater. This was evident in the current drought where it was the only unregulated stream in the Gwydir catchment to maintain flow until early 2020 when rainfall provided replenishment flows to all tributaries.

Myall Creek (catchment area 983 km²) has more zero flows (885 days) than Halls Ck. During this study flow disconnected at the lower end of Myall Creek near the flow gauge but did not cease in the mid and upstream sections. The river bed at the lower end of Myall Creek is predominantly a sandy substrate making this section a losing stream.

No gauge is available for Rocky Creek, although based on the assemblage of macroinvertebrates sampled it was evident the creek had experienced a drying event at the same time as the Horton River. The Horton River has the largest catchment (2,252 km²) and the highest high, median and low flow metrics but also the most zero flow days in both the upper and lower sections, with the upper section drying more frequently (Figure 6).



Figure 5. Aerial image of a riffle in Rocky Creek, one of the unregulated streams of the Gwydir valley. Top right (photo: Jan Hamrsky) shows two common mayfly taxa and the bottom left (photo: Jan Hamrsky) shows a net building caddisfly common in riffles.

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Water access rules in Halls Creek, Myall Creek, Rocky Creek, and the Horton River

The rules which restrict low flow water take from these streams are known as cease-to-pump (CtP) rules. The upper Horton River, Myall Creek, Rocky Creek and Halls Creek all have no visible flow CtP rules. These allow water to be accessed until stream flow stops. The lower Horton River has a flow gauge based CtP rule set at 4 ML/d.

Between 2008 and 2018, gauge data shows the CtP limits were reached 48%, 18%, 6% and 0% of the time in the upper and lower Horton River, Myall Creek and Halls Creek respectively (Table 1). During the study period, all streams except Halls Creek reached CtP limits (5A). The benefit of having a flow gauge based CtP rule is highlighted when flows are modelled with full water resource development (entitlement) in place (5B). Major changes to low flows are predicted under a full development scenario, for example Myall Creek would have a large increase in the number of cease-to-flow days.

In contrast, the flow gauge based CtP rule of 4 ML/d in the lower Horton River restricts water access from impacting zero flows in this management zone. Modelling suggests that if water users accessed their full entitlement every year then the number of cease-to-flow days for Halls Creek, Myall Creek and the upper Horton River would increase substantially under the current CtP rules.

Table 1. Consumptive water entitlements, cease-to-pump thresholds and trigger information for the study water sources

Water Source	Management zone	Unregulated entitlement	Cease-to-pump (CtP) threshold Very Low Flow Class	Period: 1st July 2008 to 30th June 2018	
				# days CtP triggered	% of period CtP triggered
Horton River	Upper Horton	1706 ML	No visible flow	1719	48%
	Lower Horton	3964 ML	4 ML/day	642	18%
Myall Creek	Myall Creek	1412.5 ML	No visible flow	211	6%
Rocky Creek	Rocky Creek	291 ML	No visible flow	No gauge	No gauge
Halls Creek	Halls Creek	441 ML	No visible flow	0	0%

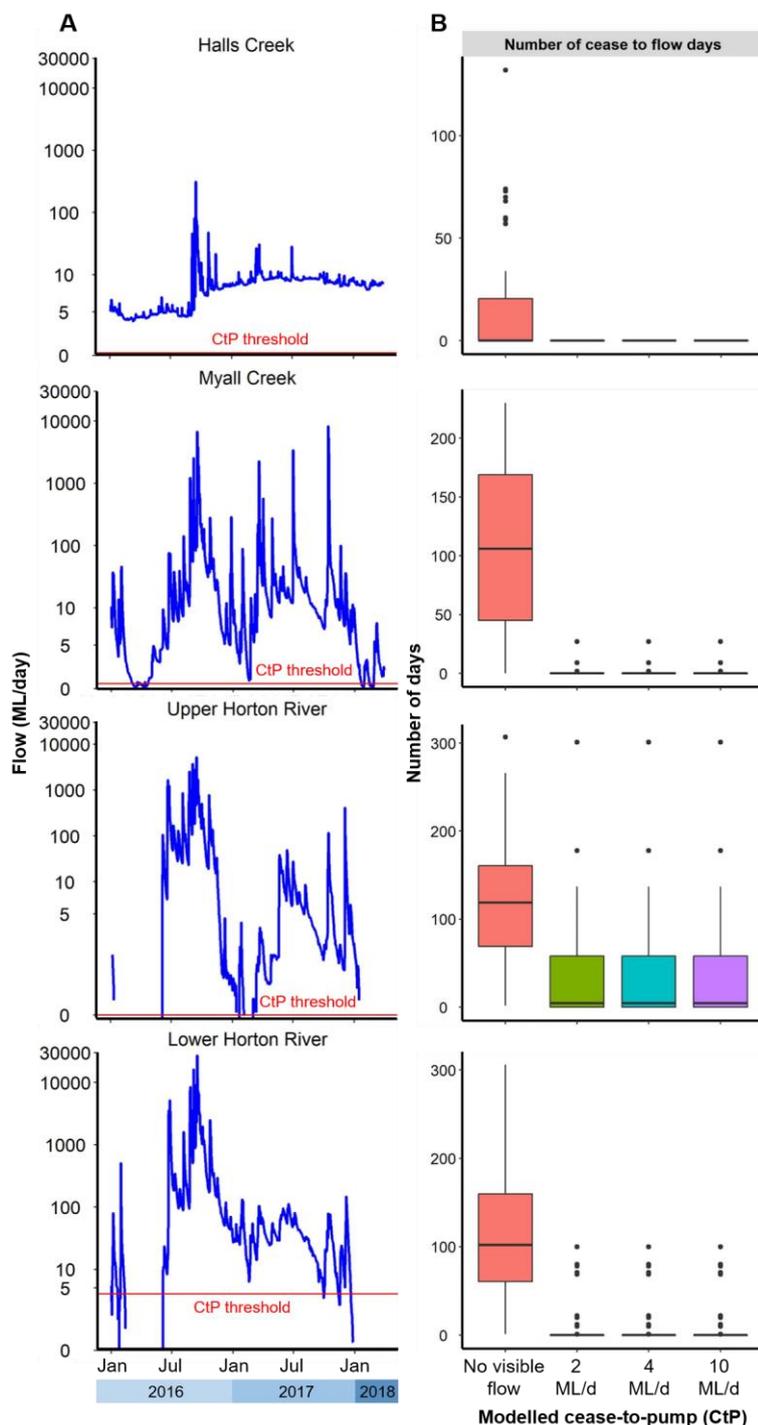


Figure 6. (A) Mean daily flow and (B) modelled number of cease-to-flow days between 1966 and 2008 with four different cease-to-pump (CtP) rules for each unregulated water gauge in this study. Modelled outcomes are based on the risk assessment for the Gwydir surface water resource plan area (SW15) (DPIE Water 2019).

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Summary and recommendations

What have we learnt about the recovery of macroinvertebrates after a cease-to-flow event?

This project highlights the time required for riffle-dependent macroinvertebrate assemblages to recover after a no visible flow period.

- Diversity can take at least a year to reach similar levels to streams which don't dry;
- Some species respond much faster than others;
- The total number of macroinvertebrates (abundance of all taxa combined) can take at least 150 days to reach the abundance of perennial streams.

In addition to the direct effects on macroinvertebrates, many native fish are dependent on macroinvertebrates as a food source (Chessman 2013). The Eel-tailed freshwater catfish (*Tandanus tandanus*, endangered population), Murray cod (*Maccullochella peelii*), Golden perch (*Macquaria ambigua*) and the endangered Purple spotted gudgeon (*Mogurnda adspersa*) all feed on macroinvertebrates during at least one life stage (Davis 1977, Sternberg et al. 2008, Kaminskis and Humphries 2009, Pusey et al. 2010). These species have all been recorded in the Rocky Creek, Horton River, Myall Creek or Halls Creek study areas. Periods of reduced macroinvertebrate diversity and abundance due to drying events may reduce food resources for juvenile and adult fish.



Figure 7. The lower Horton River during a no visible flow period (left) and after flow resumed (right).

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Do the cease-to-pump rules in these water sources protect macroinvertebrates?

Although the Horton River is an intermittent river, the flow gauge based CtP of 4 ML/d in the lower Horton River management zone provides adequate protection for macroinvertebrates. Halls Creek, Myall Creek, the Upper Horton and Rocky Creek all have no visible flow CtP rules. No visible flow CtP rules are predicted to increase the number of cease-to-flow events in both intermittent and perennial streams if all water entitlements are accessed each year. This may result in more periods of low macroinvertebrate diversity and low abundances due to the time required for recolonisation. The predicted impact of full entitlement access on cease-to-flow events will be exacerbated by predictions to changes in climate (e.g., Van Dijk et al. 2006). It is predicted that surface water availability across the Murray Darling Basin will probably decline, impacting flow regimes and water availability.

Recommendations for the replacement of the *Water Sharing Plan for the Gwydir Unregulated River Water Sources 2012* in 2022.

1. increase the CtP in Halls Creek to a gauge based CtP of 2 ML/d or more to protect the perennial nature of this stream. This will protect macroinvertebrates and improve protection for the endangered Purple spotted gudgeon which has been recorded in this water source. This flow based CtP must be linked to groundwater take as increased access to groundwater is the most likely cause of a cease-to-flow event in Halls Creek.
2. consider a study that looks at triggers that determine when water users switch between surface water – groundwater licences. This will help with the development of rigorous access conditions to protect instream pools.
3. maintain the 4 ML/d CtP in the lower Horton River management zone.
4. maintain the no visible flow CtP in the upper Horton River management zone. This management zone is predicted to experience a large number of cease-to-flow days regardless of the CtP rule.
5. consider increasing the CtP in Myall Creek (Figure 8) to at least 2 ML/d to reduce the frequency and duration of cease-to-flow events. This will improve protection of macroinvertebrate communities.



Figure 8. DPIE Water staff sampling a site on Myall Creek.

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Appendix A - Water sharing plan evaluation context for the study

The NSW Monitoring, Evaluation and Reporting (MER) framework allows water sharing plan (WSP) monitoring, evaluation and reporting activities to deliver on specific agency requirements; and contribute to a broader understanding of water management and river and wetland health. The Gwydir Surface Water Environmental [MER Plan](#) was designed to monitor outcomes for water sharing plans, water quality management plans, and long-term water plans to meet reporting requirements under Schedule 12 of the *Basin Plan 2012* and section 43A of the *Water Management Act 2000*.

Protection of baseflows

The highest risk to ecosystems in unregulated rivers occurs when flows are low, or cease, and the demand for water is high (Figure 6).

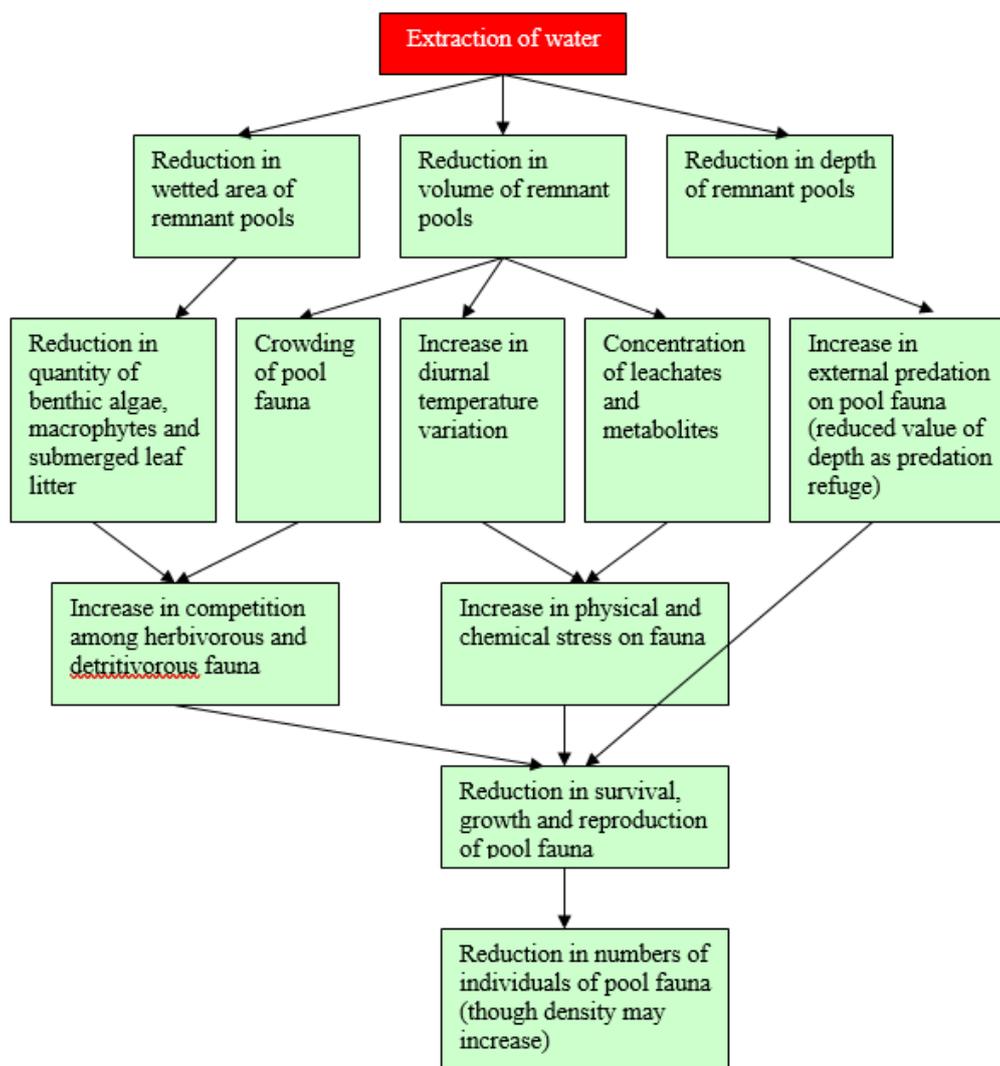


Figure 6 Aquatic ecosystem responses to water extraction in river pools under no-flow conditions. Responses will vary according to natural patterns of water loss and timing, frequency and magnitude of extraction

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Why are these water sources relevant?

The risk assessment for the Gwydir surface water resource plan area (SW15) examined risks to the environment and to environmental water requirements from water extraction at low flows for both zero flow period and baseflow metrics (Table 2). High risk outcomes were determined for four of the five locations examined in this study. Risks were calculated using an ecological value consequence metric and a hydrologic likelihood metric. All water sources support recorded populations of Eel-tailed catfish (endangered population), with other threatened or endangered species in some water sources (e.g., Purple spotted gudgeon in Halls Creek; Bell's turtle in Myall Creek).

Table 2. Water sources and overall risk to these assets. Adapted from the Gwydir Surface Water Risk Assessment (DPIE Water 2019)

Water source or management zone	Risk outcomes for insufficient water for the environment and environmental water requirements	
	Zero flows	baseflows
Halls Creek	high	medium
Myall Creek	high	high
Rocky Creek Management Zone	medium	medium
Upper Horton Management Zone	high	high
Lower Horton Management Zone	low	high

Water sharing plan objectives

The *Water Sharing Plan for the Gwydir Unregulated River Water Sources (2012)* contains objectives relevant to the protection of baseflows in unregulated rivers linked to strategies and rules that establish flow and extraction thresholds for the protection of river health (Table 3 and Table 4). These objectives, strategies and performance indicators are relevant to other WSPs across NSW including but not limited to the:

- Border Rivers Unregulated Water Sources (2012)
- Namoi and Peel Unregulated Water Sources (2012)
- Macquarie Bogan Unregulated Rivers Water Sources (2012)
- Castlereagh Unregulated Rivers Water Sources (2011).

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Table 3. Relevant water sharing plan objectives

Objectives	Strategy	Performance indicator
<p>Protect and contribute to the enhancement of high diversity hotspots and significant habitat for native fish, frogs, waterbirds, native vegetation and <i>low flow macroinvertebrate communities</i> in water sources that are susceptible to increased frequency and duration of low flows and drying.</p> <p>Intent: Protect and contribute to the distribution or extent of recorded target ecological populations including low flow macroinvertebrate communities in water sources that are susceptible to increased frequency and duration of low flows and drying.</p>	<p>Restrict the take of water from in-river (and off-river) pools when the volume of that water is less than full capacity.</p>	<p>The changes or trend in the recorded range, extent or condition of the targeted ecological population.</p>

Table 4. Relevant water sharing plan rules

Water source	Management zone (MZ)	CtP trigger ¹	CtP reference point	Trade into management zone
Halls Creek	Halls Creek MZ	No visible flow	Halls Creek at Bingara gauge (418025), 0.1m at gauge	Not permitted
Myall Creek	-		Individual pump site ²	
Rocky Creek, Cobbadah, Upper Horton & Lower Horton	Rocky Creek MZ		Individual pump site ²	
	Upper Horton MZ			
	Lower Horton MZ	4 ML/day	Horton River @ Rider gauge (418015), 92 nd percentile flow	

¹In the Halls Creek and Lower Horton management zones, the CtP trigger refers to the boundary between the 'very low flow' and the 'A' flow classes. ²Water cannot be taken under access licence when there is no visible flow, or when a pool has less than full capacity, unless an exemption applies; refer to the WSP for further information.

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

Appendix B - Methods

Gwydir valley study sites

Benthic macroinvertebrate samples were collected at nine sites in the unregulated tributaries of the Gwydir River below Copeton Dam. The sites covered the region just east of Bingara to the confluence of the Horton River and Gwydir River (Figure 1). Sites were restricted to cobble-stone riffle habitat across all locations. The top of the site was the most upstream section of the riffle and the bottom of the site was defined by the transition into a run or pool. One site was established in Rocky Creek, three in the Horton River, two in Myall Creek and three in Halls Creek. Sites were sampled between May 2016 and March 2018. The sites were sampled up to 12 times within this period with at least four weeks between sampling events. Some sites could not be sampled on all occasions due to cease-to-flow conditions.

Macroinvertebrate sampling and identification procedure

Benthic macroinvertebrates were collected using quantitative sampling methods for all sites. Sampling was done primarily with a Surber sampler (0.0625 m²) unless flows were too high. Higher flows were sampled using a suction sampler (0.07 m²). Both sampling methods used a mesh diameter of 250 µm. Each subsample was collected by manually disturbing the substrata for a period of 1 minute. Six subsamples were collected at random from each site and pooled into one replicate. The total area sampled for each site was 0.375 m² when using the Surber sampler and 0.42 m² when using the suction sampler. Samples were rinsed using a 250 µm sieve before being preserved in 70% ethanol.

Samples were identified to genus for all taxa except for oligochaeta (subclass) and chironomidae (subfamily). Any samples with more than 300 individuals were subsampled using a Marchant subsampler (Hoskin Scientific Limited). The percent of subsample taken varied between 10% and 50%. Final abundances were multiplied up to account for subsamples in the final dataset.

Data analysis

All analyses and figures were done with R (RStudio 2019), Microsoft Excel (2016) and Microsoft PowerPoint (2016).

Accounting for different benthic macroinvertebrate sampling methods

There was a slight difference between the area sampled by the Surber sampler and that of the suction sampler (0.0625 m² vs 0.07 m²). In addition, the Surber sampler relies on stream flow to collect macroinvertebrates whilst the suction sampler is powered by a battery operated bilge pump. To test for any difference between sampling techniques, samples were collected at one site in the Gwydir River across three time periods using both the Surber and suction sampler. The total abundance and diversity or richness was calculated for each sample. Total abundance was log transformed and diversity was kept as the raw number of taxa present. We performed a one-way Student's t-test to identify if the mean total abundance and mean diversity for the Surber sampler was significantly less than the suction sampler. There was no significant difference between methods for total abundance ($t_{(1)} = -0.19$, $p = 0.43$) and diversity ($t_{(1)} = 0.34$, $p = 0.38$). These results suggest combining data collected by both sampling methods would not have a significant impact on the quantified measurement of macroinvertebrate in this study.

Hydrological and CtP analysis

A range of hydrological analysis were required for this study. These included:

1. time series plots for mean daily flow during the study period
 - This included representation of the cease-to-pump threshold in unregulated streams

Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

2. box plots of 10% of the mean daily flow (an estimate of low flows) and the median daily flow to describe flow at available locations
3. summary flow metrics to describe the hydrology of each site
4. summary hydrological modelled outcomes from the integrated water quantity and quality simulation models developed for the Risk Assessment for the Gwydir Surface Water Resource Plan Area (SW15): Part 1, Schedule D.

This information was used to describe water source CtP frequencies, site hydrology and assess the benefits of visible flow cease-to-pump rules.

Recovery of macroinvertebrates after a no visible flow period

At the beginning of this study, the intermittent streams in the region had experienced cease-to-flow periods of at least 100 days before flow recommenced. As the nearby perennial sites had not experienced a drying event, the pool of regional species or taxa was considered the expected macroinvertebrate assemblage without a cease-to-flow flow period. Therefore, the time required for an intermittent stream to reach a similar composition of taxa to those nearby perennial streams was assessed. Both species abundance and presence-absence data were used to answer this question. A pool of taxa collected on each sampling event was generated using all perennial sites (three in Halls Ck and two in Myall Ck). This was considered the 'local' pool of taxa. The number of shared taxa for each site and sample date was calculated using the 'betapart' package in R Studio and converted into a percent. The percent of shared taxa at each intermittent (three in the Horton River and one in Rocky Ck) site through time was then calculated. This was then compared to the number of days since flow recommenced at each site. The relationship between the increase in shared taxa and days since flow was explored using non-linear models and ANOVAs for each site and river. Sites were pooled into 'rivers' where appropriate.

Taxa abundance data was analysed for all taxa combined (total) and the eight most abundant genera/subfamilies found across all intermittent sites. The most abundant taxa and their total abundance was *Austrosimulium* (47,430), *Simulium* (15,765), *Cheumatopsyche* (14,247), *Offadens* (10,408), subfamily Orthocladiinae (9,120), subfamily Chironominae (8,347), *Tasmanocoenis* (6,261) and *Jappa* (2,849). Abundance data was $\log(x+1)$ transformed to identify change in abundance after flow recommenced. The relationship between abundance change and days since flow was explored using non-linear models and ANOVAs for each site. Sites were not pooled for this analysis.

More information

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Cease-to-pumps and macroinvertebrates

Monitoring, evaluation and reporting – Basin Plan

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