Recovery of macroinvertebrate communities after environmental flows to the Snowy River below Jindabyne Dam 2000 – 2016

Summary

The Snowy Water Initiative provides for environmental water releases. These flows improve the health of rivers affected by the Snowy Hydro-electric Scheme. This report documents the responses of freshwater invertebrate communities to environmental flows in the Snowy River below Jindabyne Dam (Snowy River Increased Flows).

What did we study?

Freshwater invertebrates play a critical role in aquatic ecosystems. More than 60% of freshwater invertebrates are insects. Many insect species spend their juvenile life stage in streams and rivers, emerging onto land to develop into flying adults. Freshwater invertebrates process organic matter, cycle nutrients for microbial and plant growth, and facilitate energy flow through food webs. They provide a vital link between primary producers such as algae and microbes and predators such as fish, birds and turtles.

What did we find?

- Environmental flows to the Snowy River below Jindabyne Dam began in 2002. Mean daily flows were 39 megalitres per day (ML d^{-1}) before the environmental flow releases. Mean daily flows increased to 411 ML d^{-1} during the high flow Environmental Flow Releases period between 2010 and 2016.
- The increased flow to the Snowy River reduced the impact of the dam. This resulted in benthic macroinvertebrate communities in **riffle** habitats (areas of shallow fast flowing water) at all sites resembling communities in nearby unregulated rivers which are unaffected by the dam.
- Macroinvertebrate communities in **pool-edge** habitats (areas of slow flow) became less impaired and more like communities in unregulated reference sites throughout the delivery of the first two Environmental Flow Releases (in 2010 and 2011). These releases increased baseflows from Mowamba weir and Jindabyne Dam. However, the variability of Snowy River communities increased after the high flow Environmental Flow Releases began in 2011. The greater frequency of high flows likely caused the sandy substrate in pools to mobilise more often. This continually disturbed the macroinvertebrate community.
- Changes to the trophic structure (the proportion of different functional feeding groups such as filter feeders, grazers and predators) of macroinvertebrates with increasing flows over time indicated changes to macroinvertebrate habitat and food resources. These changes related to the removal of fine particulate organic matter. This resulted in the trophic structure of Snowy River communities resembling communities in unregulated rivers.

What does this mean for water management?

- The patterns of change in macroinvertebrate community composition and trophic structure show that Environmental Flow Releases have improved communities. They resemble those found in nearby unregulated rivers. These changes took over 15 years to achieve. This suggests that recovery processes in highly regulated rivers are slow.

Recovery of macroinvertebrate communities

Snowy River Increased Flows: 2000 – 2016

Flow regulation and management in the Snowy River

Large dams regulate river flows, changing the natural flow regime, reducing species diversity and altering the composition of communities in river ecosystems. Dams can also affect aquatic plants and animals by reducing the complexity of downstream habitats, increasing sedimentation, modifying the temperature regime, and fragmenting river ecosystems which can isolate populations of aquatic biota. Flow restoration below dams aims to mimic some elements of the pre-regulation flow regime, resulting in changes to the ecosystem so that it resembles a more natural state, similar to ecosystems observed in nearby unregulated streams.

The Snowy River is regulated by four major water storages and other smaller diversions as part of the Snowy Mountains Hydro-electric Scheme (SMS). In addition to generating electricity, the Scheme is used to regulate the supply of water for irrigation in the Murrumbidgee and Murray valleys in conjunction with downstream irrigation dams. The Snowy Water Initiative (SWI) was established in 2002 to improve river health by releasing environmental water into the Snowy, upper Murrumbidgee, and upper Murray river systems. Embodied in the Snowy Water Inquiry Outcomes Implementation Deed 2002 (SWIOID 2002), the SWI is an agreement for water recovery and environmental flows between the New South Wales (NSW), Victorian and Australian governments (the partner governments) and Snowy Hydro Limited. The SWI provides for increased environmental flow regimes to adjust for the diversion of river flows by the SMS. The Snowy River Increased Flows (SRIF) releases environmental water from Jindabyne Dam to improve the health of the Snowy River in NSW and Victoria.

This study reports on the outcomes of long-term monitoring by DPIE Water of the recovery of macroinvertebrate communities after the provision of an environmental flow regime (EFR) to the highly regulated **Snowy River below Jindabyne Dam**.

Recovery of macroinvertebrate communities

Snowy River Increased Flows: 2000 – 2016

Jindabyne Dam releasing environmental water to the Snowy River.

Figure 1. Environmental water released to the Snowy River from Jindabyne Dam.

The diversion of water from the Snowy River below Jindabyne Dam significantly reduced river discharge between 1967 and 2002, with mean annual discharge reduced to 1 per cent following the development of the SMS. With the aim of improving the ecological condition of the Snowy River, baseflows were increased from 2002 to 2010 by releasing environmental water from Mowamba River (2002 – 2006) and Jindabyne Dam (2006 – 2010). Each year after 2010, in addition to further increasing baseflows, a number of large flow events were released from Jindabyne Dam to mimic the natural high flow regime of the Snowy River (Figure 1).

Study design

Benthic macroinvertebrates[1] were collected from four sites in the Snowy River below Jindabyne Dam and two sites in nearby unregulated rivers (Thredbo River and Mowamba River) (Figure 2). At each site, macroinvertebrates were quantitatively sampled from two habitats, riffles (areas of shallow fast flowing water, and pool – edges (areas of slow flow). Samples were collected in spring and autumn from 2000 – 2009 and in autumn only from 2010 – 2016. There were no samples collected in 2013.

[1] Benthic macroinvertebrates are bottom-dwelling invertebrates that can be seen with the naked eye.

Location of macroinvertebrate sampling sites in the Snowy River between 2000 – 2016.

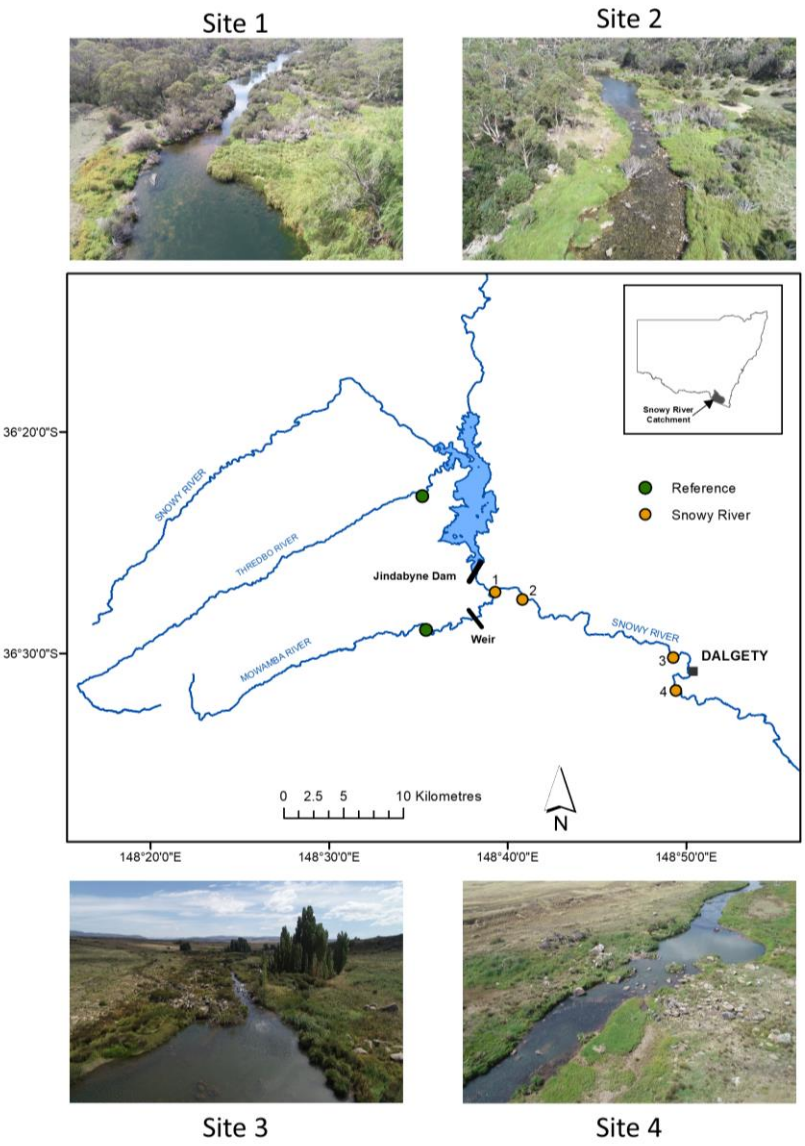


Figure 2. Map of macroinvertebrate sampling sites in the Snowy River catchment.

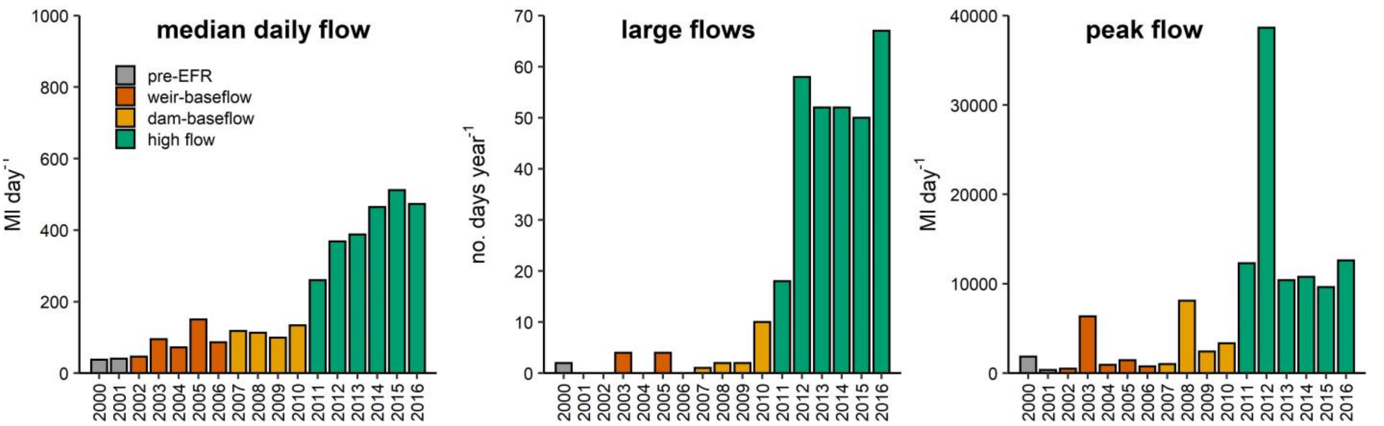
Recovery of macroinvertebrate communities

Snowy River Increased Flows: 2000 – 2016

Increased flows to the Snowy River

There were two distinct changes to the flow regime (hydrology) after the provision of the EFR began in 2002. Between 2002 and 2010, environmental water releases increased median daily flows from 39 megalitres per day (ML d^{-1}), to 90 ML d^{-1} during releases from Mowamba weir and 115 ML d^{-1} during releases from Jindabyne Dam (measured at Dalgety; Figure 3). The larger EFR releases between 2010 and 2016 further increased median daily flows to 411 ML d^{-1} and the number of days of high flow events (flows > 1000 ML d^{-1}) per year increased from 0 – 10 to 18 – 67 after 2010 (Figure 3). The annual peak flow also became much greater during the post-2010 high flow EFR period. Notably, there was a peak flow of almost 40,000 ML day^{-1} in 2012 which was caused by a natural catchment-wide rainfall event. All Snowy River sites and reference sites were affected by this rare flow event.

Changes to hydrology in the Snowy River after the provision of the environmental flow regime



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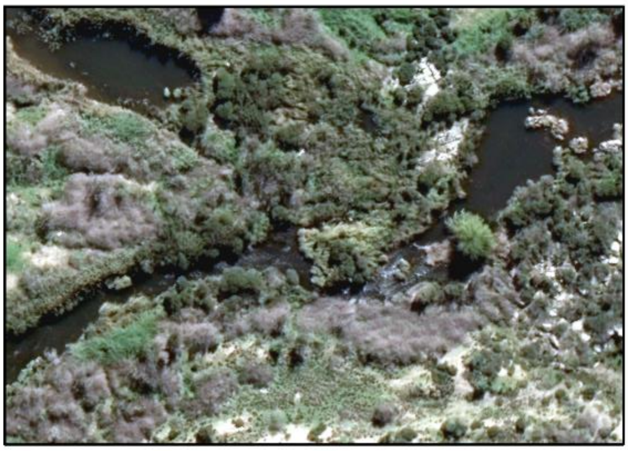

2019

Figure 3. Changes to mean daily flows (ML day^{-1}), frequency of large flows (> 1000 ML day^{-1}) and the annual peak flow after the provision of increased baseflow EFR and high flow EFR. Flows were measured at Site 4 (Dalgety; gauge no. 222026). Images show geomorphic changes to Site 3 riffle habitat between 2010 and 2019.

Invertebrate communities become more natural after increased flows

Changes to macroinvertebrate community composition

During the period of increased baseflows and high flows to the Snowy River from Mowamba weir and Jindabyne Dam, the composition of the benthic macroinvertebrate communities at all **riffle** sites became more similar to reference communities in nearby unregulated reference rivers (Figure 4). For example, densities of caenid mayflies (Caenidae), which are usually associated with slower flowing silty areas, were reduced by the increased flows, approaching the levels of unregulated streams. Conversely, the densities of leptophlebiid mayflies (Leptophlebiidae) increased throughout the EFRs to numbers equal to those of unregulated (or reference) sites. These community changes were significantly associated with the improved EFR in the Snowy River, particularly the increases in daily flows and high flows (both large and peak flows). These findings indicate that the increased flows to the Snowy River from the EFR was a major contributor to the recovery of invertebrate communities within riffles.

Comparison of Snowy River and reference invertebrate communities throughout the EFRs

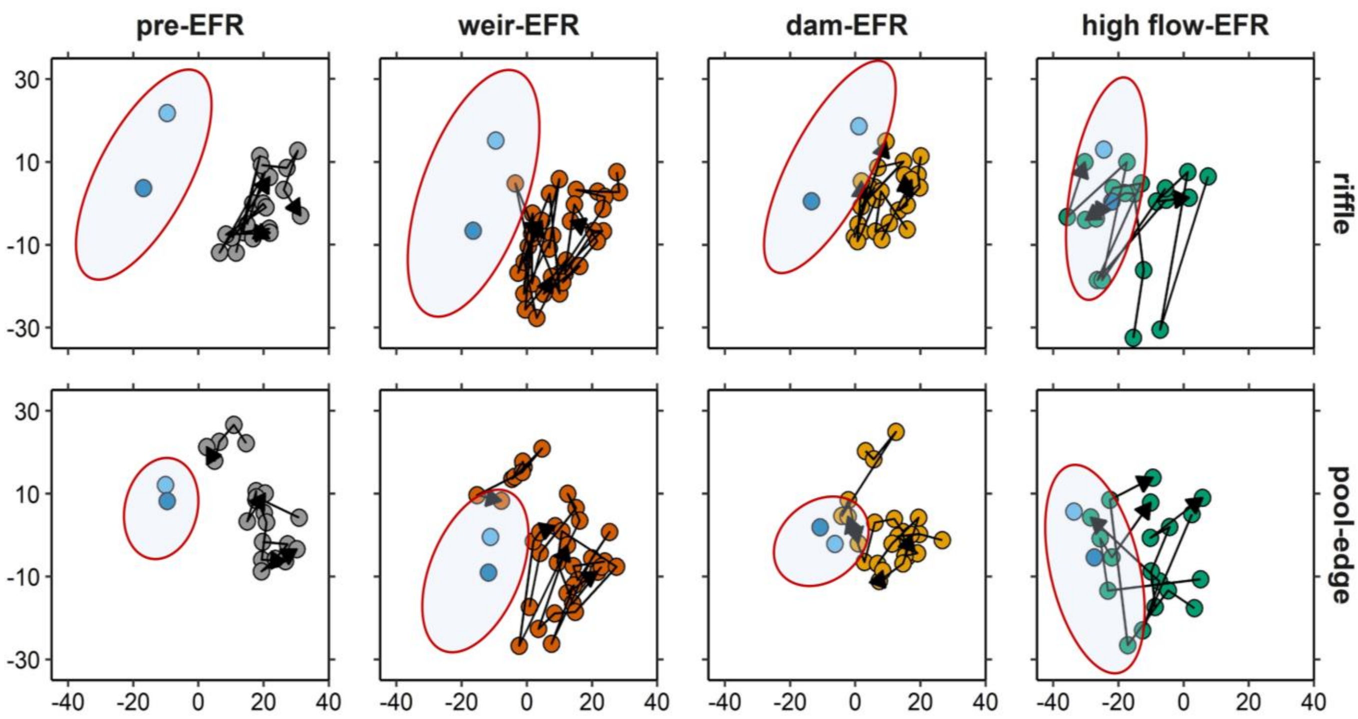

Figure 4. Changes in community composition between invertebrate communities in the Snowy River and the reference sites (Thredbo River – dark blue, Mowamba River – light blue; points represent the average of reference samples within individual EFR periods) under different flow regimes. Sample points that are close together in the ordination indicate they possess similar invertebrate communities. Ellipses show the range of reference samples within an EFR period.

Recovery of macroinvertebrate communities

Snowy River Increased Flows: 2000 – 2016

Pool-edge invertebrate communities became similar to reference sites throughout the first two EFRs (increased baseflows from Mowamba weir and Jindabyne Dam). However, there was a substantial increase in the variability of Snowy River communities after the high flow EFR releases from Jindabyne Dam began in 2011 (Figure 4). This appears to be from an initial disturbance in the Snowy River from the first large flows in 2011, followed by the catchment-wide natural flood in 2012, the latter of which affected habitats in both the Snowy River and reference sites. The large flood in 2012 may have created a large disturbance and reset community assembly processes in all locations, contributing to the overall variability in similarity between Snowy River and reference invertebrate communities during the high flow EFR. Despite the effects of the flood, the reduction in total invertebrate densities and changes to densities of individual taxa (⬆ baetid mayflies, ⬇ worms) indicates the Snowy River invertebrate community is becoming more similar to unregulated rivers.

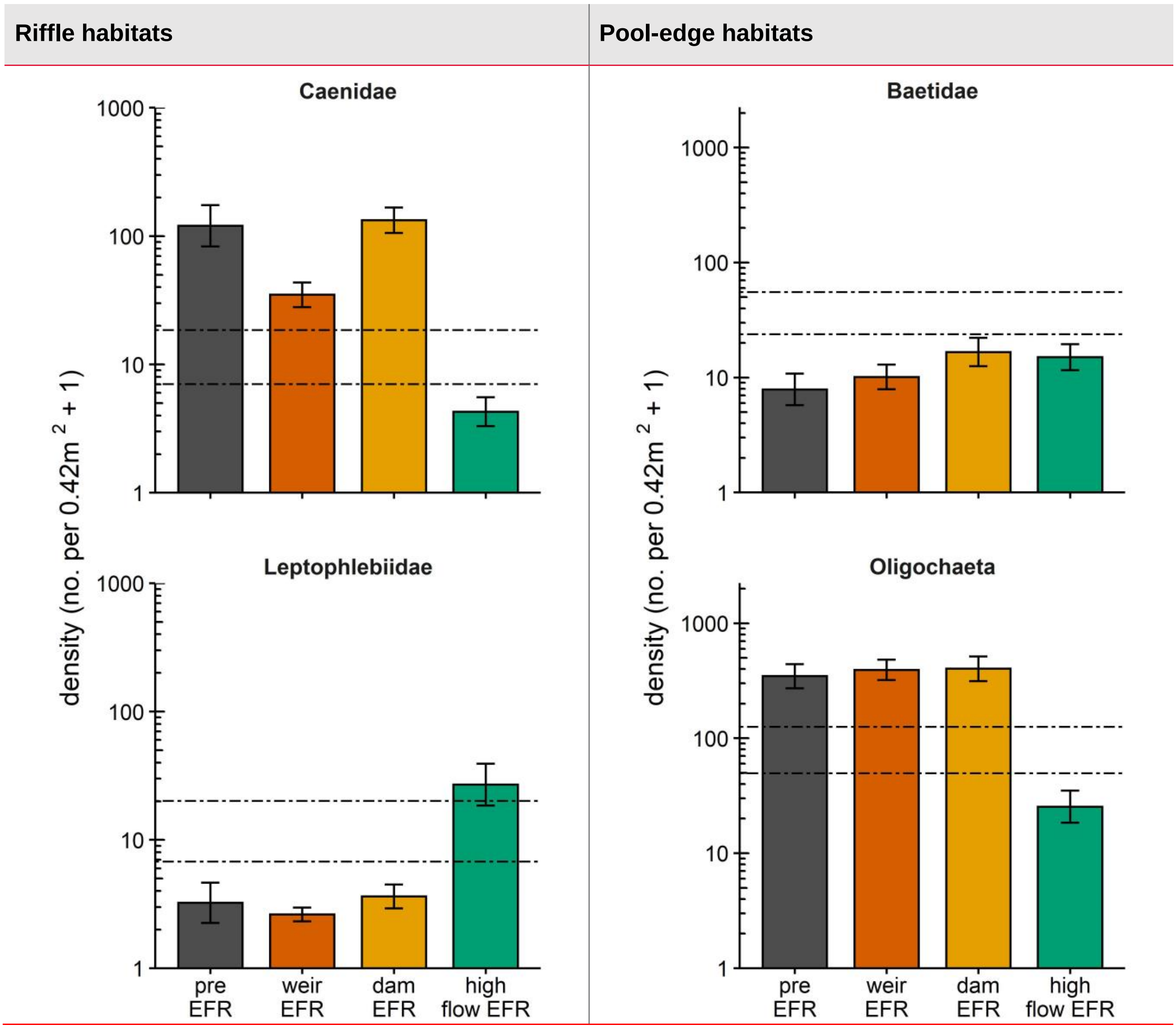

Figure 5. Mean densities of selected individual taxa from all Snowy River sites. Dashed lines represent 95% confidence intervals of reference sites.

Changes to trophic structure

We also evaluated changes to community trophic structure using functional feeding groups to assess whether abiotic environmental conditions (e.g. habitat) or biotic (living) factors like competition and predation may have influenced community patterns. Scrapers consume food from a variety of algal sources including single cells (attached and loose) or colonies of non-filamentous algae and also fine detritus (Figure 6). These food resources and the scrapers that feed on them are generally found in fast flowing water habitats (i.e. riffles) or in depositional areas (i.e. pools) that receive regular scouring flows. Gatherers feed on fine particulate organic material and associated bacteria deposited on fine sediments in pools, stream margins or within crevices in coarse sediments in faster flow (Figure 6). Filter-feeders capture fine particulate organic matter from moving water using silk nets or adaptations to body parts and predators catch and consume live prey (Figure 6).

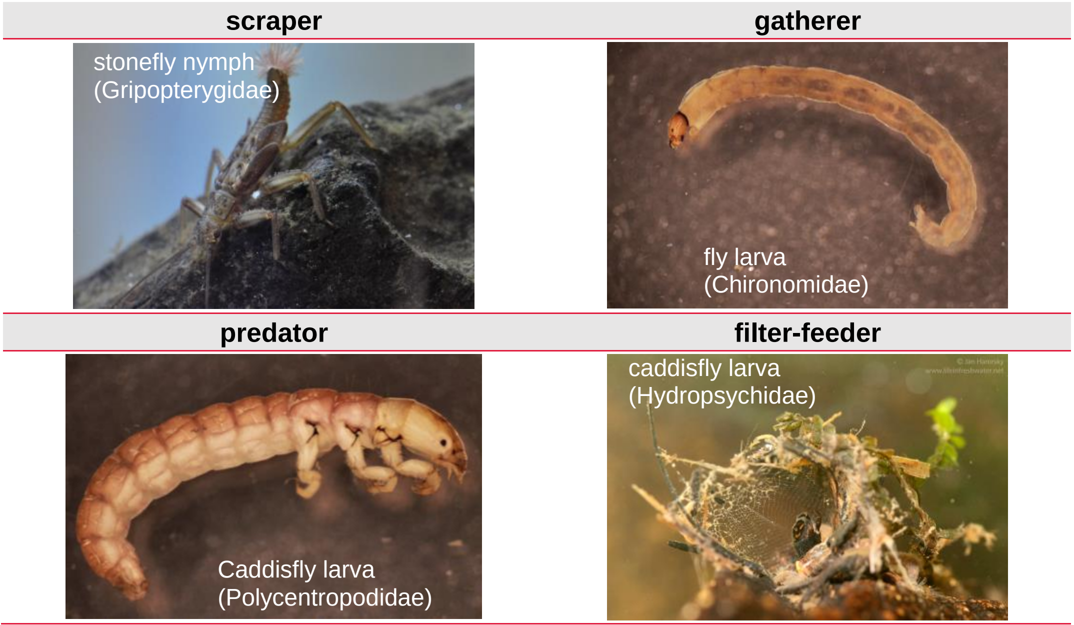

Figure 6.Examples of the four main invertebrate functional feeding groups: scrapers, gatherers, predators and filter-feeders.

The temporal changes to the trophic structure of both riffle and pool-edge invertebrate communities in the Snowy River was limited to scrapers and gatherers and revealed the influence of the EFRs on food resources and habitat conditions. The average densities of scrapers in riffle habitats of the unregulated river reference sites comprised a greater proportion of the invertebrate community than gatherers (27% vs 14%, Figure 7). Conversely, a greater proportion of gatherers than scrapers occurred in the slower flowing pool-edge habitats (30% vs 12%, Figure 7). These patterns in functional feeding groups are typical of communities in rivers with unaltered flow regimes.

In the Snowy River sites, gatherers were dominant in both habitats in the early part of the study, reflecting the reduced flows prior to the high flow EFRs. Furthermore, the relative abundance of gatherers was much higher than reference communities in both habitats (Figure 7), averaging more than 50% of invertebrates in the pre-EFR sampling period. As the EFR increased flows, the relative abundance of gatherers decreased and scrapers increased, with values of both groups of invertebrates becoming comparable to reference river communities during the period of the high flow EFRs. The exception was in Site 1, where the relative abundance of scrapers in both habitats and of gatherers in pool-edge habitats were equal to reference sites throughout the study. This was possibly because this site was located in a gorge close to Jindabyne Dam. This constriction is likely to have increased the velocity of the flows leading to communities that had not diverged greatly in trophic structure from reference communities despite decades of low lows.

Our results indicate that the increased base-flows and high flow EFR scoured fine sediment and biofilms in riffle and pool-edge habitats, rehabilitating the physical habitat and food resources within the Snowy River. These changes to local environmental conditions altered the trophic structure of macroinvertebrate communities, leading to a community that resembled nearby unregulated rivers.

Changes to trophic structure

riffle habitat	pool-edge habitat

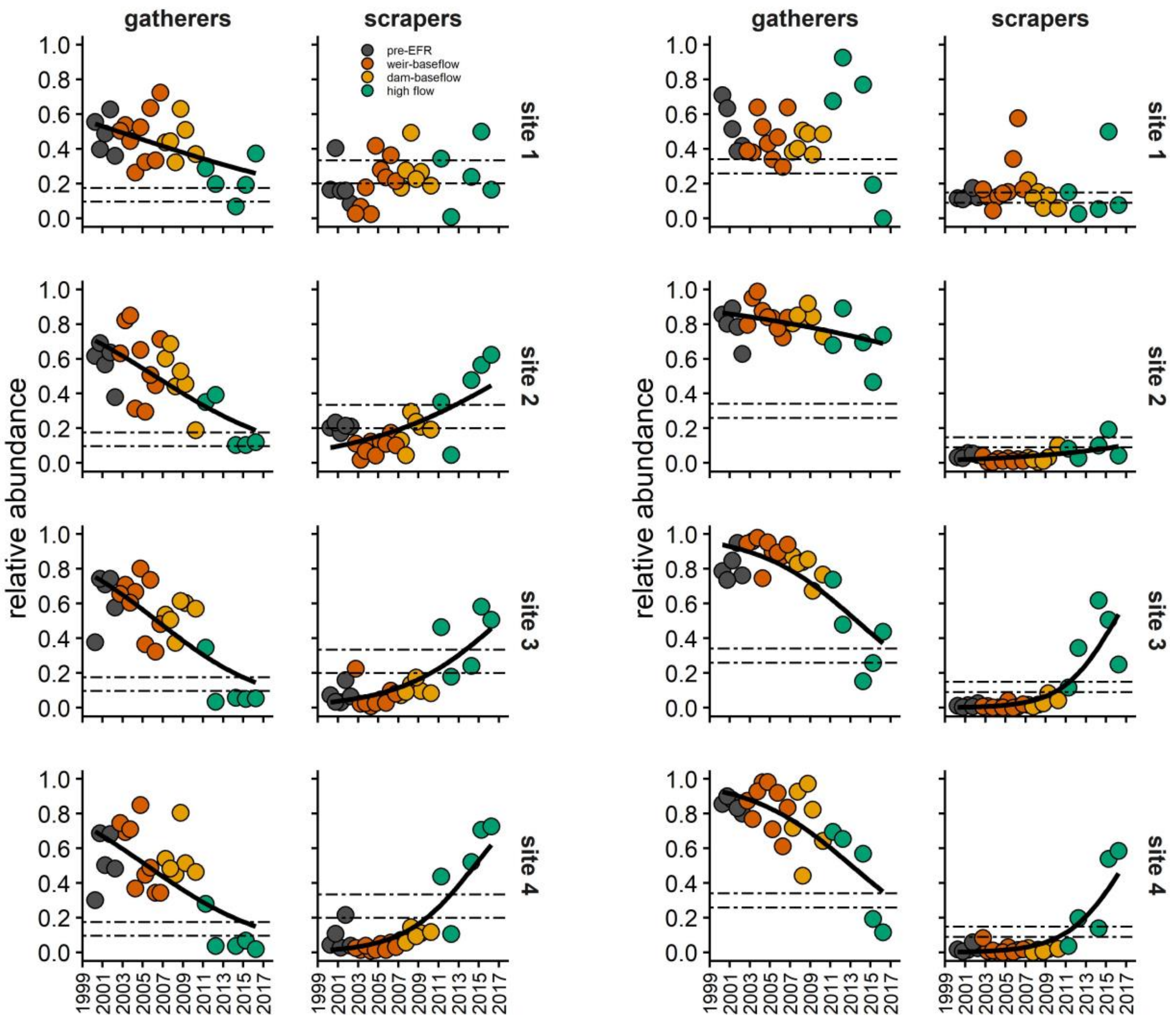

Figure 7. Temporal patterns of scraper and gatherer macroinvertebrate functional feeding groups over the EFRs. Dashed lines represent the 95% confidence intervals of reference sites.

Conclusions

Overall, the patterns of change in macroinvertebrate community composition and trophic structure have shown that the EFRs have altered the communities so they now resemble those found in unregulated rivers. The high flow EFR was key to altering habitat and food resources leading to alterations to community composition. These changes took over 15 years to achieve and suggest that recovery processes in highly regulated rivers are slow. Furthermore, long-term monitoring is required to establish the success of such environmental flow programs.

Recovery of macroinvertebrate communities

Snowy River Increased Flows: 2000 – 2016

More information

Andrew Brooks

Senior Ecohydrologist

andrew.brooks@dpie.nsw.gov.au

Water | Department of Planning, Industry and Environment

84 Crown St. | PO Box 53 | Wollongong NSW 2520 Australia

Daniel Coleman

Senior Ecohydrologist

daniel.coleman@dpie.nsw.gov.au

Water | Department of Planning, Industry and Environment

84 Crown St. | PO Box 53 | Wollongong NSW 2520 Australia

Detailed methods

Macroinvertebrate sampling

Macroinvertebrates were sampled from three random points in each of two riffles and edges of two pools at each site (the total number of subsamples for each habitat was six) using a suction sampler for 1 minute at each sampling point (total area sampled = 0.42 m^2). Pool-edge samples were collected from depths of 0.2 – 0.5 m within 2 m of the bank. The six subsamples were pooled for analysis.

All macroinvertebrates (except for segmented and unsegmented worms) were identified to family level. The segmented worms were identified to class (Oligochaeta) and unsegmented worms to phylum, except for flatworms which were identified to order (Tricladida).

Statistical analysis

Patterns of community assembly. We tested whether benthic invertebrate community composition in the Snowy River sites became more similar to reference communities after the provision of the EFR.

1) Principal coordinates ordination (PCO) using the Bray-Curtis coefficient on $\log_{10}(x+1)$ transformed data was used to visualise overall macroinvertebrate community patterns in between Snowy River sites and reference sites for each EFR period.
2) The relationship between increases to flow and changes to invertebrate community structure at Snowy River sites were related to using distance-based linear models (DISTLM).

Changes to trophic structure. We tested for relationships between the relative abundance of functional feeding groups (a proportional response) and time at each Snowy River site using generalised linear models (GLM) with a with a quasibinomial distribution to account for overdispersion.