Invertebrate responses to environmental flows in the Snowy Montane Rivers

Summary

The Snowy Water Initiative provides for environmental water releases. These flows aim to 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 montane rivers (Snowy Montane Rivers 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?

- Newly formed invertebrate communities in re-wetted tributary riverbeds resembled unregulated reference sites after two years. These riverbeds had been dry for more than 50 years.
- Drift from the intact upstream invertebrate communities was the primary source of colonisation in the new communities.
- Invertebrate communities in the main-stem of the Snowy and Geehi regulated rivers received significant increases in flow. The new invertebrate communities in the tributaries increased the numbers and diversity of colonists arriving via drift to the regulated river sites. Increase in densities occurred only in a single feeding group (filter feeders), not the whole community.

What does this mean for water management?

- Environmental flows provided to selected Snowy montane tributaries restored invertebrate communities. Restoration was reliant on an intact source of upstream colonists.
- Environmental flows from tributaries to main-stem regulated rivers may have limited benefit to invertebrate communities.
- In highly regulated rivers, successful restoration may need large releases of water. This would provide a greater diversity of microhabitats and create disturbances to help colonisation of new taxa. The result would be a more natural community.

Snowy River above Guthega Pondage	Snowy River below Island Bend Dam
	

Background

Dams and weirs regulate river flows, modifying the natural flow regime, reducing species diversity and altering the composition of biological communities in river ecosystems. Changes to the flow regime can affect aquatic plants and animals by reducing downstream habitat complexity, increasing sedimentation, and modifying the temperature regime. In addition, dams and weirs disrupt longitudinal connectivity and isolate populations of aquatic biota, potentially limiting dispersal along rivers. 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.

The Snowy Mountains Hydro-electric Scheme captures and diverts the headwaters of numerous alpine and montane streams (12 rivers and 71 creeks). The Scheme includes 16 dams, 18 aqueducts, 19 trans-mountain tunnels, 7 power stations and 2 pumping stations. In addition to generating electricity, the Scheme regulates the supply of water for irrigation in the Murrumbidgee and Murray valleys in conjunction with downstream irrigation dams. Impoundments and diversions throughout the Snowy River catchment have severed flow connections between much of the Snowy River catchment and its headwaters. Until 2002, ninety-nine percent of mean annual flows from the upper catchment were diverted to the Murrumbidgee and Murray rivers through a series of weirs and impoundments, disrupting the natural flow regime to downstream reaches and impacting on aquatic communities.

Geehi reservoir

The Snowy Water Initiative (SWI) was formally established in 2002 to achieve significant improvements in river health by releasing environmental water into the Snowy, upper Murrumbidgee, and upper Murray river systems. The SWI is formalised in the Snowy Water Inquiry Outcomes Implementation Deed 2002 (SWIOID 2002), an agreement for water recovery and environmental flows between the NSW, Victorian and Australian governments (the partner governments) and Snowy Hydro Limited.

The NSW Government is responsible for the implementation of the SWI. The SWI provides for three increased environmental water flow regimes to adjust for the diversion of river flows by the Snowy Hydro-electric Scheme: (i) **Snowy River** – environmental water to be released every day from Jindabyne Dam as Snowy River Increased Flows (SRIF), to improve the health of the Snowy River in New South Wales and Victoria; (ii) **Snowy montane rivers** – environmental water to be released as Snowy Montane Rivers Increased Flows (**SMRIF**); and (iii) **River Murray** – environmental water delivery to the Murray River as River Murray Increased Flows (RMIF).

This study reports on DPIE Water long-term monitoring of the recovery of macroinvertebrate communities after the provision of the environmental flows to the **Snowy montane rivers** provided under the SMRIF.

Study design

This study was centred upon two cobble-bed creeks in the montane area of the Snowy Mountains, Middle Creek and Diggers Creek. These creeks are tributaries of the regulated Geehi River (regulated by Geehi Dam) and Snowy River (regulated by Island Bend Dam), respectively and situated in different catchments approximately 16 km apart (Figure 1, Figure 2). On each tributary, a weir was used to divert almost all stream flows into nearby dams for hydropower generation and diversion to different catchments for irrigation. Thus, the stream sections downstream of these weirs have previously been dry for > 50 years and contributed no flow to the downstream regulated rivers except during floods. In each case, the stream affected by the weir was the first major tributary to an established community downstream of the large dams (Geehi and Island Bend).

The river channels below the dams had no inflowing water, but a small amount of groundwater input created aquatic habitat that supported benthic (bottom-dwelling) invertebrate communities.

As part of the SMRIF, a decision to decommission the aqueducts on the weirs of these tributaries allowed all flows to overtop the weirs and provide water to the previously dry riverbeds of the tributaries, and additional flows to the main-stem regulated rivers further downstream.

Middle Creek weir	Diggers Creek weir
	

Middle Creek weir	Diggers Creek weir
	

Figure 1. Weirs in Middle Creek and Diggers Creek pre- and post-flow releases

We studied freshwater insect communities to address two main questions:

a) did the provision of environmental flows from the weirs lead to successful colonisation in the tributary? This was determined by comparing the structure of the newly assembled communities in the tributary to the source of colonists upstream of the weir (reference sites).

b) Did the increased flow from the tributaries affect the invertebrate community in the regulated river sections? We determined whether the new communities in the tributaries increased the numbers and diversity of dispersers to existing impacted communities downstream in the regulated river, altering their composition to resemble the unimpacted upstream reference sites.

Sample sites (elevation 1100 m – 1250 m) were grouped into Reference (upstream of the weirs), Tributary (i.e. tributary sites with newly developing communities) and Regulated (i.e. regulated sites with an established community) locations with a different number of sites in each location for each method of sampling (Figure 2). The weirs on both rivers were approximately 1 km upstream from the confluence with the regulated rivers. The study rivers are located entirely within montane woodland zone of the Kosciuszko National Park in the Snowy Mountains region and consequently are unaffected by any other human impacts.

Middle Creek → Geehi River	Diggers Creek → Snowy River

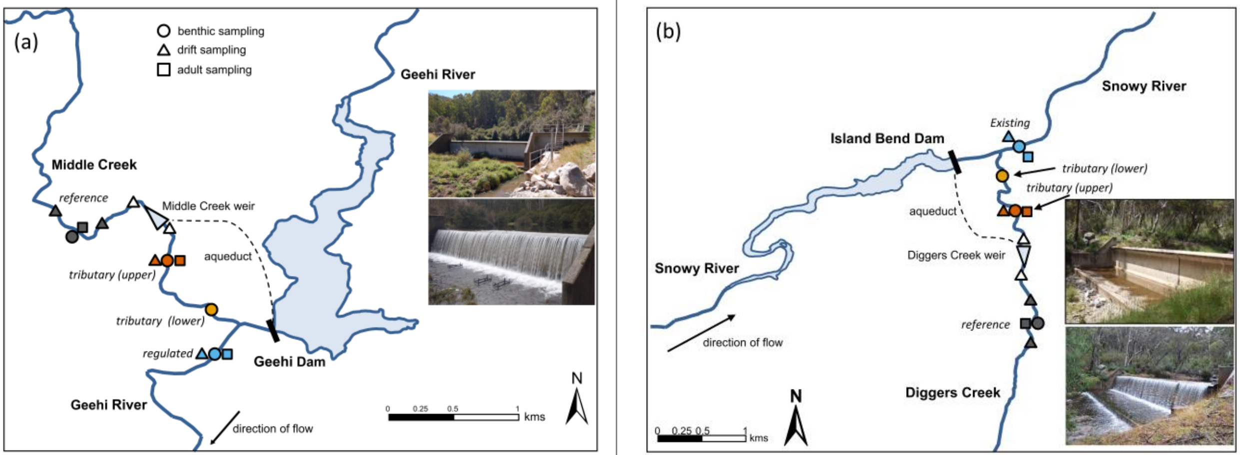


Figure 2. Location of sampling sites in Middle Creek / Geehi River and Diggers Creek / Snowy River

Benthic samples were collected from Reference sites upstream of the weirs, two sites in the tributaries below the weirs (Tributary [upper], Tributary [lower]) (Figure 2, Figure 3) and one within the regulated river (Regulated). Benthic samples were collected twice in the Reference and Regulated locations in both rivers prior to the decommissioning of the aqueducts and from all locations on 6 occasions after flows from the weir began (approximately 1, 7, 11, 16, 20, 22 months post-release). Additionally, to understand the role of dispersal in the colonisation of the tributary and regulated communities, drifting invertebrates and winged adults were also sampled (Figure 2, Figure 3).

First, we carried out tests to characterise patterns of community change in the newly formed tributary communities and established regulated benthic communities after the increase in flows. Next, we evaluated changes to community trophic structure using functional feeding groups to assess whether abiotic environmental conditions or competition and predation may have influenced the colonisation and recovery of macroinvertebrate communities.

Sampling benthic invertebrates	Invertebrate drift and adult light trap sampling
	

Figure 3. Sampling methods for benthic invertebrates, drifting invertebrates and flying adults.

Invertebrate responses to environmental flows

Colonisation in the previously dry tributaries

Within the tributaries, benthic communities that formed after the release of water into the previously dry streams rapidly resembled reference sites after two years, and this pattern was consistent between the rivers (Figure 4). Dispersal via drift from the reference communities upstream was clearly fundamental to colonisation. The weirs significantly affected downstream dispersal via drift, altering the assemblage composition entering and exiting the weir by reducing total drift rates, taxon richness, the drift rates of gatherers, scrapers and filter-feeders. In addition, flying adults were not present in the tributaries in the first year after flows resumed, and thus colonisation via egg laying was unlikely. So, although there was evidence of dispersal limitations, they had little effect on invertebrate community recovery in the tributary locations.

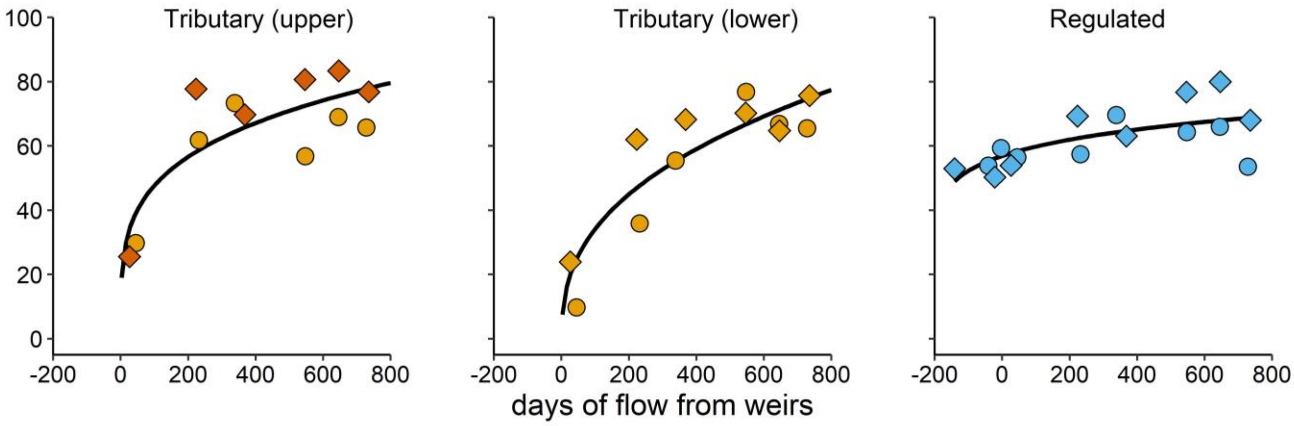


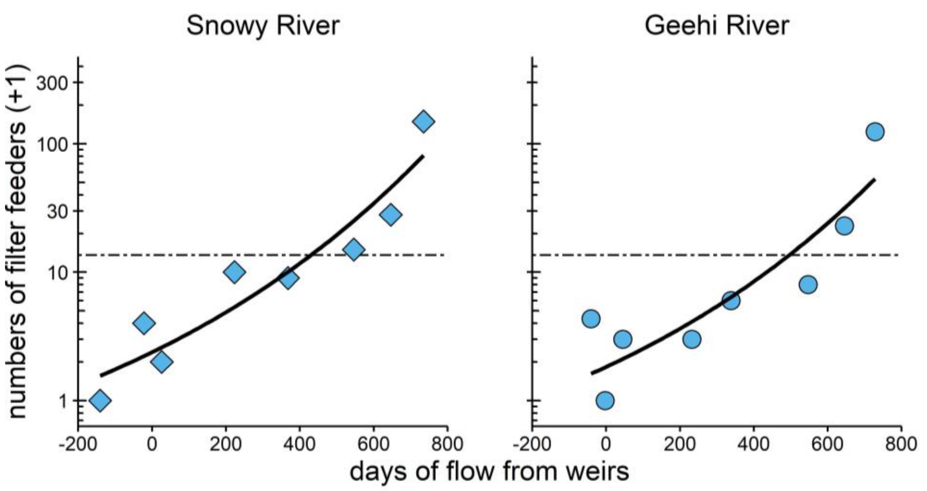
Figure 4. Invertebrate community similarity to reference communities after flows was released from the weirs. Circles = Middle Creek / Geehi River, diamonds = Diggers Creek / Snowy River.

Influence of increased flow and dispersal on the established communities in the regulated rivers

Discharge in the regulated river sections with an existing impacted invertebrate community increased 28 – 56 fold after stopping the diversion of water at the weirs within the tributaries, equating to 5 – 10 % of natural flows. The new invertebrate communities in the tributaries increased the numbers and diversity of colonists arriving via drift to the regulated river sites, but this boosted dispersal had no strong effects on existing communities. Rather than causing changes across the whole regulated community, there was only an increase in the densities of filter feeders, leading to a limited increase in community similarity to Reference sites (Figure 4, Figure 5).

Filter feeders remove particulate matter from suspension, consuming living organisms and both organic and inorganic detritus. They also play an important role in the flow of energy and productivity in freshwater environments. The increased discharges effected a change to environmental conditions by increasing the area of fast-flowing habitat in what was previously slow-flowing, resulting in more space for filter feeders. Filter-feeder drift rates did not increase, suggesting that the new colonists may have originated via greater recruitment from egg-laying adults or local drifters.

Response of filter feeders to increased flows in the regulated rivers



Filter feeders

(*Cheumatopsyche* sp.)

Figure 5. Response of filter feeding invertebrates in the regulated rivers after increased flow from the tributaries. Dashed line represents the mean filter feeder densities in reference sites

Implications for management

- Our study illustrates that invertebrate communities can quickly recover when natural channels are re-wetted by environmental flows, even those that have been dry for decades. These flows delivered dispersers from intact locations upstream, even in the presence of significant barriers (e.g. weirs) that reduced dispersal.
- Nevertheless, boosting flows and densities of dispersers from tributaries had no strong effects on existing invertebrate communities. Instead, increased discharges effected a reduction in environmental conditions, which sightly altered trophic structure.
- In highly regulated rivers, successful restoration may require large releases of water from dam structures to provide a greater diversity of microhabitats and create disturbances to initiate a new round of community assembly, leading to a more natural community.

More information

Brooks A.J., Lancaster J., Downes B.J. and Wolfenden B. (in press) Just add water. Rapid assembly of new communities in previously dry riverbeds, and limited long-distance effects on existing communities. *Oecologia*

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Detailed methods

Benthic invertebrate sampling

On each sampling occasion at each site, quantitative samples were collected using a suction sampler (total area sampled = 0.42 m^2). Each sample was subsampled (20% – 50%). Invertebrates were identified to genus and enumerated, except for Chironomidae, which were identified to sub-family. Invertebrates were assigned to one of four functional feeding groups (predators, filter feeders, gatherers and scrapers).

Invertebrate drift sampling

Invertebrate drift was sampled using drift nets (25 x 25 cm opening) fitted with 1.5 m long nets with 250 μm mesh. At each site, three nets were located along a transect perpendicular to the flow of water. Nets were completely submerged at approximately 0.6 of maximum depth and at least 3 cm above the stream bed. Drift was collected on two nights over 3 hr starting 15 min prior to sunset, which is the period when invertebrate drift rates are at a maximum. Sample methods for drift exiting the weirs were slightly different, with metal frames used to orient drift nets perpendicular to the flow overtopping the weir wall. Six nets were placed in random positions beneath the flow of water falling from the weir. All samples were preserved in 70% ethanol and samples collected at a site (3 or 6 nets and 2 nights) were composited, subsampled, identified and enumerated in the laboratory using the protocols as for benthic samples. Chironomidae were not identified in drift samples due to resource constraints.

To estimate drift rates, we calculated the proportion of the cross-sectional area of the water column sampled by drift nets, and used this to estimate the total number of individuals of each taxon drifting at each sampling location. Thus, drift rates were the total number of insects drifting past the sampling point on the river per 3 hr.

Flying adult invertebrate sampling

Winged adults play an important role in recolonisation of rivers via oviposition and are a potential source of colonists. We sampled flying invertebrate adults at the Reference, Tributary (upper) and Regulated sites using light traps (8 W, 12 V ultraviolet fluorescent tube) placed above a white bucket with an ethanol wick dispenser, which released ethanol fumes into the bucket and killed trapped insects. A single light trap was placed overnight at each site, and each site was sampled on 2 nights. Samples were preserved in 70 % ethanol and composited over the 2 nights and identified to genus.

Statistical analysis

We tested whether communities at Tributary and Regulated locations converged on a natural community (i.e. Reference sites) after flows over the weir began. Community similarity (Bray-Curtis coefficient, $\log_{10}(x+1)$ transformed data) was calculated between pairs of sites for three separate comparisons (Reference vs Tributary [upper], Reference vs Tributary [lower] and Reference vs Regulated) on each sampling occasion and for each river. Each comparison was analysed using least squares linear regression to test for temporal patterns in community similarity. *t*-tests were used to determine if the slopes of the relationships were significantly different from zero. A positive slope indicates that the community became more similar to upstream reference sites. The regression model was a linear form of a power function using log-transformed values of both similarity and time, because we expected colonisation processes to initially be rapid before slowing or reaching an upper limit over time. Densities of functional feeding groups were analysed using the linear regression methods described above using an exponential model.