Ecological response to an experimental high flow release in the upper Yarra River, Victoria, Australia

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Key Points

- This paper presents the results of ecological monitoring during an experimental high flow release into the upper Yarra River at Reefton, Victoria, Australia.
- Additional habitat in the littoral zone and higher up the banks was inundated during the release providing flow refuge for macroinvertebrate communities, fish populations and platypus.
- There were decreases in abundances of several macroinvertebrate taxa but no notable changes in community composition.
- River Blackfish (*Gadopsis marmoratus*) persisted following the releases although there was an increase in the average length of individuals.
- Results from this investigation indicate that high flow releases can be made into the upper Yarra River without compromising ecological conditions.

Abstract

The successful delivery of recommended environmental flows throughout the Yarra River depends on the ability to deliver sufficient water into the system. Constraints to this include the capacity of upstream reaches to tolerate the high flows required to meet environmental objectives of downstream reaches. We investigated the influence of a 600 ML/day experimental high flow release on ecological conditions in the upper Yarra River at Reefton, Australia. The higher than recommended release was required to provide a migration and spawning cue for EPBC listed Australian Grayling (*Prototroctes maraena*) in a downstream reach and to transport larvae to the estuary and sea. Firstly, we found that additional physical habitat was inundated during the release that could provide refuge for macroinvertebrates, fish and platypus. Secondly, while there were changes in abundances of macroinvertebrate taxa the community composition was unchanged. Thirdly, native River Blackfish (*Gadopsis marmoratus*) persisted following the release although there was an increase in average length of the population. The results of this investigation increase the understanding of ecological risks due to high flow releases. We make recommendations on incorporating a high flow release to address environmental objectives throughout the Yarra River.

Keywords

Environmental flows; high flows; monitoring; environmental objectives; ecological conditions

Introduction

In lotic ecosystems the flow regime is considered the major determinant sustaining and influencing ecosystem structure and function (Poff and Zimmerman, 2010; Webb *et al*., 2013). Changes to the flow regime can influence multiple components of an aquatic ecosystem including habitat (Gore *et* *al.,* 2001), water quality (Olden and Naiman, 2010), macroinvertebrate communities (Bunn and Arthington, 2002) and fish populations (Broadhurst *et al.*, 2011). In regulated rivers and streams environmental flows can aid in reinstating characteristics of the natural flow regime with subsequent benefits to aquatic ecosystems (Dyson *et al.,* 2003).

Environmental flow recommendations have been developed for six freshwater reaches in the regulated Yarra River (Treadwell, 2005; Sharpe *et al.,* 2012). The recommendations are based on the FLOWS method that determines environmental flow requirements to meet reach-based environmental objectives (State of Victoria, 2002). These flows are considered to be the minimum required to achieve an ecologically healthy river and any reduction will compromise the ability for this to be achieved (Sharpe *et al.,* 2012). Flow recommendations for the Yarra River have been developed for summer/autumn (December to May) and winter/spring (June to November) and include a number of flow components such as freshes, high flows, low flows, bankfull and overbank flows (Sharpe *et al.,* 2012).

With regard to the Australian Grayling (*Prototroctes maraena*) which is listed as vulnerable under the EPBC Act, a summer/autumn high flow of at least 1,300 ML/day is required to provide a cue for migration and spawning and to transport larvae to the estuary and sea (Sharpe *et al.,* 2012). Sharpe *et al.,* (2012) assessed compliance of flow in the Yarra River to recommended environmental flows and found that suitably high flows were often not being delivered to all downstream reaches. If adequate high flows do not occur due there is a risk to the short-lived Grayling that require frequent spawning events to maintain the population (Sharpe *et al.,* 2012).

To meet environmental objectives of downstream reaches additional releases from upstream storages may be required. However, summer/autumn high flows are not recommended for the upper Yarra River and the maximum release volume (combined with tributary flow) has been set at 200 ML/day (Sharpe *et al.,* 2012). This volume was developed to minimise risks to native fish and macroinvertebrates in situations where the upper Yarra River is used to transfer water to meet recommended flows downstream (Sharpe, 2014). Maximum winter/spring releases of 300 ML/day were developed to aid in the removal of fine sediments from pool habitats and inundate vegetation in the littoral zone (Sharpe *et al.,* 2012).

The release recommendation for the upper Yarra River, particularly during the summer/autumn period, is compromising the ability to meet high flow targets in downstream reaches. Not delivering these critical flow events may be more detrimental to overall environmental objectives than delivering higher than normal flows in upstream reaches (Sharpe, 2014). To account for this Sharpe (2014) reviewed the maximum allowable releases from the Upper Yarra Reservoir and suggested that 600 ML/day is potentially the maximum flow that can be delivered without causing significant ecological impacts. Before committing to these high flow releases, Sharpe (2014) recommended that an experimental release occur and ecological conditions be monitored.

The objective of this investigation was to monitor the ecological conditions of the upper Yarra River prior to and following an experimental high flow release of 600 ML/day during the summer/autumn period. The main risks associated with delivering higher than recommended flows in the upper Yarra River relate to disturbances to geomorphology (e.g. erosion), macroinvertebrate communities, native fish populations (particularly River Blackfish) and platypus (Sharpe, 2014). Based on the risks identified by Sharpe (2014), we monitored aquatic habitat, macroinvertebrate communities and fish populations. Results test the assumptions and risks relating to high flows in the upper Yarra River and provide information to allow flexibility in the delivery of future environmental water releases from the Upper Yarra Reservoir.

Methods

Monitoring was carried out prior to and following the 600 ML/day experimental release during the summer/autumn period (see dates in Figure 1). Additional monitoring was also carried out in association with a 300 ML/day release during the winter/spring period. Monitoring occurred at three sites within a 5 km reach of the Yarra River extending from the Upper Yarra Reservoir to Armstrong Creek (Table 1). Flow was assessed by producing a hydrograph based on release volumes from the Upper Yarra Reservoir and flow data from the Doctors Creek flow gauge (#229103A). The gauge is within the study reach, approximately 1 km downstream of the Reservoir and downstream from the Doctors Creek confluence. To examine the influence of the 600 ML/day releases on changes to physical habitat two field based cameras (HC500 Hyperfire) were deployed at each site and programmed to take photographs of significant microhabitats at 2 hour intervals.

Table 1. Location details for the three sites monitored in this investigation in Reach 1 of the upper Yarra River.

Site Code	Location	Latitude	Longitude	Example Photograph
YAR0342	Downstream of spillway in Upper Yarra Reservoir Park, Reefton	-37.670639	145.892163	
YAR0352	Near entrance to Upper Yarra Reservoir Park, Reefton	-37.673636	145.874589	
YAR0358	Downstream bridge at Woods Point Road, Reefton	-37.675497	145.858175	

From each site five replicate macroinvertebrate samples were collected from a riffle/run habitat using a Surber sampler as recommended by Sharpe (2014). The samples were processed based on the method of Walsh (1997) to allow a quantitative assessment of changes in communities. Most taxa were identified to family level using published keys listed in Hawking (2000). Consistent with the EPA Victoria (2003) protocol, midge fly larvae (Chironomidae) were identified to sub-family while water mites and worms (Oligochaeta) were not identified beyond these taxonomic levels. To visualize changes in the communities non-metric multidimensional scaling (nMDS) ordinations were produced and analyses of similarities (ANOSIMs) were used to determine if there were statistically significant differences between *a priori* defined groups (see Clarke and Warwick, 2001). All data was square root transformed to increase the influence of rare taxa (see Clarke and Warwick, 2001). Three separate one-way ANOSIMs were conducted to answer three different questions:

1. Are there differences in the macroinvertebrate communities prior to and following the 600 ML/day experimental release?
2. If differences were detected prior to and following the 600 ML/day experimental release is there evidence of 'recovery' before the 300 ML/day release?

3. Are there differences in the macroinvertebrate communities prior to and following the 300 ML/day release?

Fish monitoring was carried out in accordance with established protocols (Robinson and Melbourne Water 2013) and the Australian Code of Electrofishing Practice (SCFFA, 1997). Backpack electrofishing (Smith-Root LR-20B electrofisher) occurred along a minimum 350 m reach at each site (up to 500 m). Note that only two sites were monitored for fish prior to and following the 300 ML/day release. Changes in water level due to the 600 ML/day release were assessed to identify the risk to platypus based on criteria listed in Sharpe (2014). Two automated data loggers were deployed at each site (Level TROLL® 500 Series Data Loggers) that recorded water level every fifteen minutes.

Results

Flow and physical habitat

Yarra River flow closely followed the pattern of the releases indicating that hydrology was predominately influenced by the releases rather than tributary flow from Doctors Creek (Figure 1).

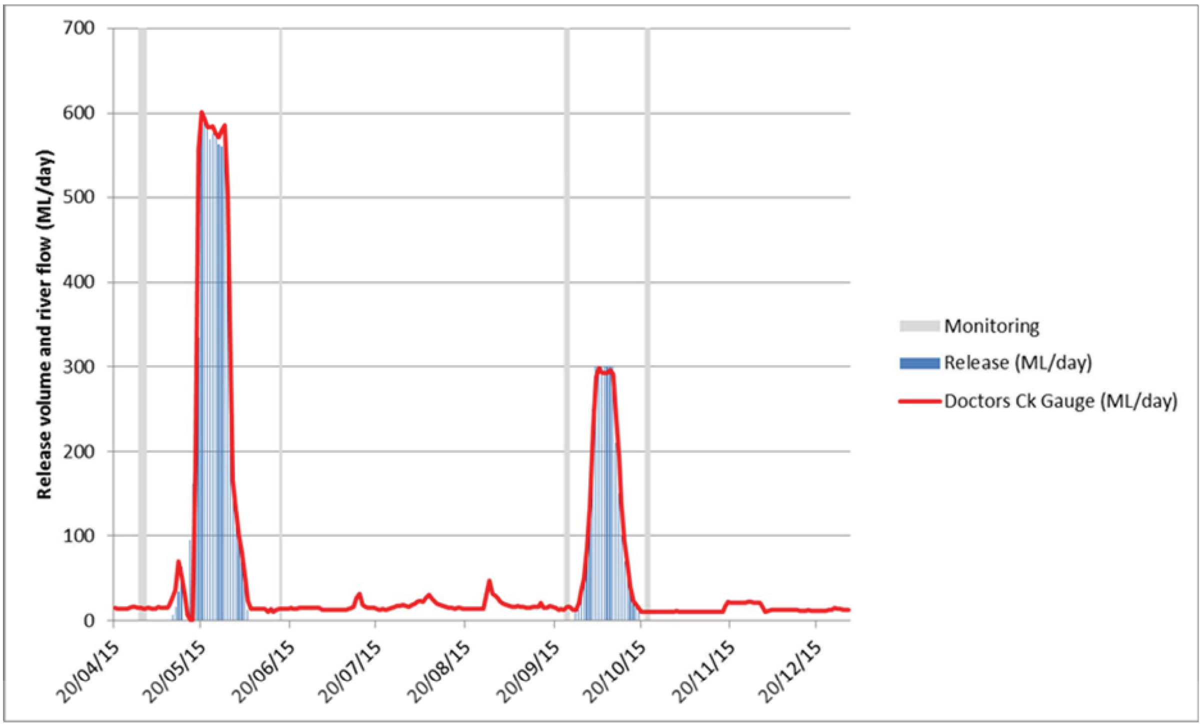

Figure 1. Release volumes from the Upper Yarra Reservoir and river flow based on the Yarra River gauging station at Doctors Creek (#229103A). Gray bars indicate the pre-release and post-release monitoring periods.

All sites were in a relatively undisturbed condition compared to urban reaches of the Yarra River. At YAR0342 there were areas dominated by silt prior to the 600 ML/day release that remained after the release had ceased (Figure 2). The preferred habitat of River Blackfish is flowing streams with an abundance of emergent vegetation, woody debris, undercut banks and rock type substrates that provide shelter from flowing water (Koster and Crook, 2008; Broadhurst *et al*., 2011; Balcombe *et al*., 2011). These types of habitat were found to persist following the cessation of the 600 ML/day release (Figure 3 and Figure 4).

Figure 2. Depositional areas of silt at the most upstream site (YAR0342) prior to the 600 ML/day release (left) and following the release (right).

Figure 3. River Blackfish habitat in the form of woody debris at the most upstream site (YAR0342) prior to the 600 ML/day release (left) and following the release (right).

Figure 4. River Blackfish habitat in the form of emergent macrophytes at the most downstream site (YAR0358) prior to the 600 ML/day release (left) and following the release (right).

At each site over 550 photographs were taken by the field based cameras during the 600 ML/day release. Example photographs of instream habitat associated with a riffle habitat at YAR0342 are included in Figure 5. The photographs clearly indicate that a range of habitat types (e.g. woody debris, emergent macrophytes and rocky substrates) were inundated during the 600 ML/day release but persisted once the release had ceased. Refuge habitat higher up on the banks was also inundated during the high flows. These changes in habitat were generally consistent at all three sites.

Figure 5. Examples of time-lapse photographs in a riffle habitat at YAR0342. Photographs were taken prior to the 600 ML/day release (top), during the release (middle), and following the release (bottom).

Macroinvertebrate communities

Surber samples collected prior to and following the 600 ML/day release are clearly separated from one another on the nMDS ordination plots suggesting that there was a change in the macroinvertebrate community (Figure 6). A similar, although less obvious pattern, was detected between the pre-release and post-release periods associated with the 300 ML/day release.

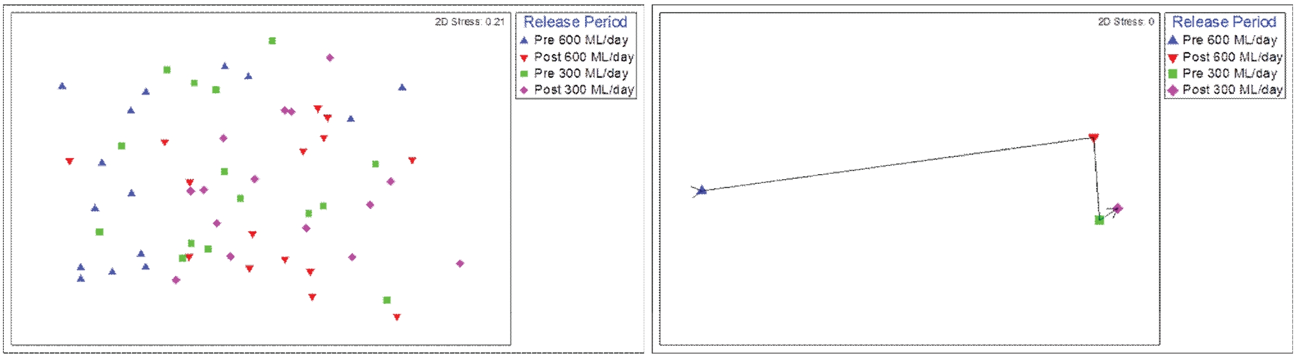

Figure 6. Non-metric multidimensional scaling (nMDS) ordination plot of macroinvertebrate communities associated with the Surber samples collected at each of the three sites (left). Duplicate nMDS ordination plot based on the centroid point for each of the four groups (right). Symbols represent samples collected prior to and following the 600 ML/day and 300 ML/day releases.

The patterns on the nMDS were validated using the three separate one-way ANOSIMs that found there were significant differences in the macroinvertebrate community prior to and following the 600 ML/day release (Global R 0.305, $P = 0.001$). The 600 ML/day post-release community also differed to the community prior to the 300 ML/day release (Global R 0.206, $P = 0.001$). There were no differences in the macroinvertebrate community between the 300 ML/day pre-release and post-release periods (Global R 0.074, $P = 0.077$).

The changes in the macroinvertebrate community following the 600 ML/day release were predominately due to decreases in abundances of several taxa including worms (Oligochaeta), mayflies (Leptophlebiidae and Baetidae), caddisflies (Hydroptilidae, Hydropsychidae, Conoesucidae and Hydrobiosidae), riffle beetle larvae (Elmidae) and stoneflies (Gripopterygidae). These taxa generally increased in abundances between the 600 ML/day release and the 300 ML/day release and this may represent a 'recovery' period while no releases were occurring. Following the 300 ML/day release there were again decreases in the abundances of these taxa. However, it should be noted that the differences in the macroinvertebrate communities prior to and following the 300 ML/day release were not statistically significant.

The focus of this investigation is to determine whether the high flow releases represent a negative or positive impact to the ecology of the Upper Yarra River. To examine this, abundance weighted SIGNAL scores (see Chessman, 2003) were calculated for the pre-release and post-release periods (Pre 600 ML/day = 0.13; Post 600 ML/day = 0.16; Pre 300 ML/day = 0.14; Post 300 ML/day = 0.17). The changes in the abundance-weighted SIGNAL scores suggest that the decrease in abundances was greater for those taxa that prefer slow flowing waters which resulted in a community that was more reflective of clean water.

Fish populations

A total of 223 individual fish were captured during the monitoring from three species; River Blackfish (*Gadopsis marmoratus*), Short-finned Eels (*Anguilla australis*) and Brown Trout (*Salmo trutta*). The abundance and length of each fish species captured during the pre-release and post-release monitoring are included in Figure 7 and Figure 8 respectively.

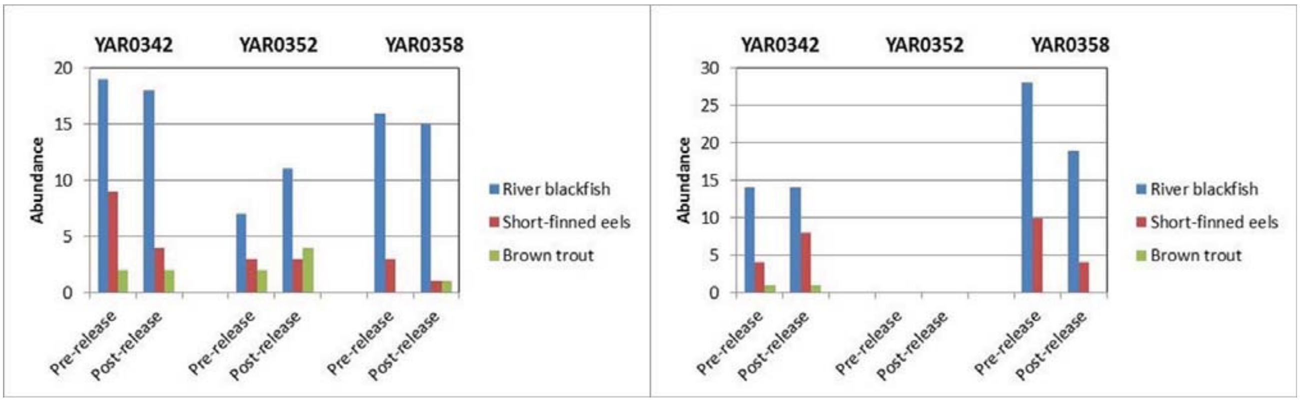

Figure 7. Number of fish captured during the pre-release and post-release monitoring of the Upper Yarra River. Results from the 600 ML/day release period are left and the 300 ML/day release period right. Note that only two sites were monitored during the 300 ML/day release.

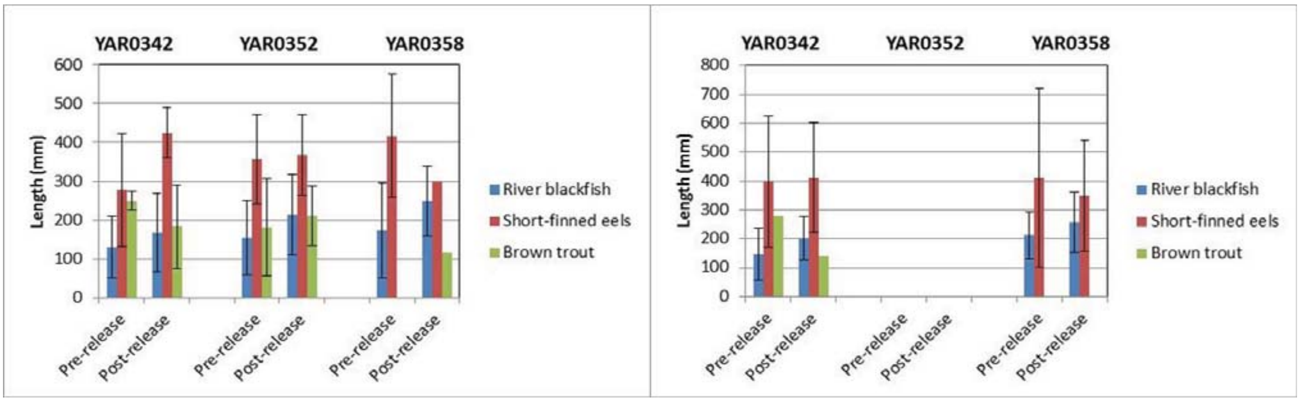

Figure 8. Mean lengths and standard deviations of fish captured during the pre-release and post-release monitoring of the Upper Yarra River. Results of the 600 ML/day release period are left and the 300 ML/day release period right. Note that only two sites were monitored during the 300 ML/day release.

Risks to fish populations due to high flows in the upper Yarra River are predominately related to River Blackfish (Sharpe, 2014) and this was the most abundant fish species captured during monitoring. As such, the focus of these results is on changes to River Blackfish populations. Changes in abundance following the releases varied amongst sites with a decrease following the 600 ML/day release at two out of three sites and an increase at one site. Following the 300 ML/day release there was no change at one site but a decrease in abundance at the other. River Blackfish were more abundant at the upstream site during the 600 ML/day monitoring but during monitoring associated with the 300 ML/day release they were more abundant at the downstream site. Following both the 600 ML/day and 300 ML/day releases there was an increase in average length of River Blackfish at all sites.

Platypus

Sharpe (2014) quantified the risk to platypus due to increases in water level in pools compared to the normal winter flow level. Consequently, changes in water levels in this investigation were assessed to identify the risk level to platypus by the use of the depth data loggers. The change in water level due to the 600 ML/day release ranged from 0.89 to 1 m. This may have implications for platypus in the Upper Yarra River with a potential burrow sighted approximately 30-50 cm above the water level prior to the 600 ML/day release.

Discussion

Fundamental to this investigation is the concept that key components of a natural flow regime influence various physical, chemical and biological processes in waterways (State of Victoria, 2002). While this concept is well accepted it is difficult to predict the direct effect of changes in flow and, more importantly, the influence of environmental flows on ecosystem changes (Poff and Zimmerman, 2010; Webb *et al.,* 2013). In part, this is because most aquatic ecosystems are impacted by multiple stressors, but it also reflects the limited understanding of flow-ecology relationships for many species and ecosystem processes (Bunn *et al.,* 2014). To better understand ecological responses to environmental flows Poff and Zimmerman (2010) suggest that the collection of pre- and post-alteration data would significantly add to our basic understanding and this has been done in this investigation. Furthermore, as the monitoring sites were immediately downstream of the Upper Yarra Reservoir in a landscape with relatively few impacts other than flow regulation, we have limited the influence of other stressors on ecological conditions. This should allow inferences on changes to ecological conditions due to releases from the Reservoir to be made with increased confidence.

Water Quality

Sharpe *et al.,* (2012) suggest that flows of 200 ML/day would generate elevated turbidity in downstream reaches that may be undesirable from an aesthetics perspective. Increased turbidity during the 600 ML/day release can be seen in Figure 5 but the levels appear to have decreased once the releases ceased. *In situ* measurements of temperature, dissolved oxygen, turbidity, pH, electrical conductivity and alkalinity were also recorded during this study (not presented). There no noteworthy differences in water quality between the pre-release and post-release monitoring for all water quality parameters suggesting that any changes due to the releases were temporary and conditions had returned to normal levels once the releases ceased.

Physical habitat

A reduction in flow in the upper Yarra River since the 1950s has resulted in the formation of lateral benches that have become stabilised by vegetation and the infilling of pools with fine organic and inorganic material (Sharpe *et al.,* 2012). One of the aims of the high flow component of the environmental flow regime is to inundate low benches within the channel and move fine sediment (Sharpe *et al.,* 2012). The field based cameras clearly determined that the 600 ML/day release resulted in the inundation of benches within the channel (Figure 5) as well as additional habitat in the littoral zone and higher up the bank. This inundated habitat could provide refuge to instream biota during periods of high flows.

Increased turbidity during the 600 ML/day release indicates that the high flows mobilized sediment in the river channel although the persistence of silt beds in the littoral zone indicate that the magnitude of flows were not great enough to remove all fine sediments from a site. However, removing all sediment and returning the channel to natural dimensions is considered inappropriate due to the potential risks associated with transporting large amounts of sediment to downstream reaches (Sharpe *et al.,* 2012). The results from this investigation indicate that releases had the capacity to remove some fine sediment from riffle and pool habitats without impacting on downstream reaches.

Macroinvertebrate communities

While there are many benefits from high flows including the flushing of sediment, restoration of lateral habitat connections and sustenance of refuge pools (Bunn *et al.,* 2014) there may also be negative impacts such as the downstream displacement or mortality of macroinvertebrates (Watts *et al.,* 2009). In a review of ecological responses to flow Webb *et al.,* (2013) determined that abundance could be negatively affected by increases or decreases in flows, diversity was only negatively affected by flow decreases, and assemblage structure was affected by neither. Poff and Zimmerman (2010), through their review, found mixed responses to changes in flow magnitude with abundance and diversity both increasing and decreasing in response to both elevated and reduced flows. On a finer spatial scale Fuller *et al.,* (2010) detected varying responses to high flows depending on the magnitude of shear stress in microhabitats, life history traits and preferred habitats of macroinvertebrate taxa. Results from this investigation suggest that the preferred habitats of macroinvertebrate taxa played a role in changes due to the releases. The general pattern of change was a decrease in abundance of macroinvertebrate taxa that do not necessarily have a preference for flowing waters (e.g. worms and midgefly larvae). This change in the community may be considered a positive effect due to the releases and could be related to the intermediate disturbance hypothesis that suggests local species diversity is maximized when ecological disturbance is neither too rare nor too frequent (Townsend and Scarsbrook, 1997).

Sharpe (2014) suggests that high flows may be more detrimental if delivered more than once per year between March and October. The influence of the 300 ML/day release was not as severe as for the 600 ML/day release and this may be due to the community having already been changed by the initial release. Therefore, if high flow releases are to be made into the upper Yarra River in the future, considerations should be given to the timing of the releases in regard to other flow components of the environmental flow regime.

Fish populations

As stated by Sharpe *et al*., (2012) River Blackfish is the species most likely to be affected by changes to the flow regime and is therefore the main focus of this investigation. There was no evidence that the abundance of Blackfish was impacted by the releases although there was some indication that larger individuals dominated the population following the releases. Metrics such as body condition are reported to perform better than abundance changes in assessing ecological responses of fish to alterations in flow (Bunn *et al.,* 2014). This is because under variable hydrological conditions abundances are strongly influenced by short-term responses of fish breeding and recruitment with high numbers of juveniles inflating abundances at particular sites (Balcombe *et al.,* 2011). River Blackfish spawn from spring to early summer (Cadwallader and Backhouse, 1983; Allen, 1989) so it is unlikely that the greater abundances of juveniles prior to the releases was related to fish breeding and recruitment.

It is difficult to ascertain the exact movements of River Blackfish during the releases without direct observations of behavior. However, Koster and Crook (2008) found that Blackfish used inundated habitat at river margins during flood periods in Armstrong Creek, a second order tributary of the Yarra River. Sharpe (2014) also suggests that flows between 500 and 600 ML/day may not be detrimental as adults can move to flow refuges at channel margins. This is important as Blackfish are thought to be relatively sedentary with home ranges from 10 to 26 m (Kahn *et al.,* 2004). Alternatively, a decrease in juvenile recruitment and/or survival of Blackfish due to floods has been demonstrated in the upper Condamine River in the headwaters of the Murray-Darling Catchment (Balcombe *et al.,* 2011). The adult River Blackfish monitored in this investigation may have avoided the high flow impacts by utilising flow refuges in the inundated channel margins of the Upper Yarra River.

Immature River Blackfish tend to remain in shallow waters, burrowing themselves under leaf litter (Jackson 1979). Although these microhabitats persisted after the releases, other studies have shown that juvenile Blackfish can be displaced downstream due to increases in flow (Doeg and Saddlier, 1993; Koster and Crook, 2008). Results from this investigation indicate that there is some potential for juvenile River Blackfish to either tolerate the releases or return upstream if they had been displaced. Koster and Crook (2008) found that it is possible that large River Blackfish occupy non-overlapping home ranges that they share with smaller, subordinate individuals as part of a dominance hierarchy. High flows provide important opportunities for individuals to explore and colonise other locations within a waterway (David and Closs, 2002; Crook, 2004).

The limited home range of adult River Blackfish (Kahn *et al.,* 2004) coupled with the colonisation of new locations by juveniles may also explain the increase in the size of the population following the releases.

Platypus

Platypus exhibit a single breeding season with mating occurring during late winter or spring and juveniles first emerge after 3-4 months of nurture by lactating females (Grant and Temple-Smith, 1998). With this in mind risks to platypus are based on increases in water level (compared to normal winter levels) from January to March when high flows may flood burrows when juveniles begin to emerge and are vulnerable (Sharpe, 2014). The risk criteria developed by Sharpe (2014) for the January to March period are: 0 – 0.5 m increase (low risk), 0.5 – 1 m increase (medium risk) and >1 m increase (high risk).

This investigation found that the 600 ML/day release increased river levels by an average of 92 cm and a maximum of 100 cm during May and early June. This is slightly greater than the estimated 50 to 80 cm increase for releases between 400 and 600 ML/day estimated by Sharpe (2014). Despite this, the releases in this investigation occurred outside of the January to March critical period. Examination of water level data from the Doctors Creek Gauge determined that the average 2015 winter (June to August) level was 0.233 m and the average level from January to March 2015 was greater than this at 0.255 m. Consequently, if a 600 ML/day release was to occur during the period when juvenile platypus at are risk (January to March) water levels may increase by greater than 1 m above winter river level which represents a high risk. In this case burrows are likely to be flooded and juveniles drowned and adults are at risk of predators because they cannot use their burrows and may be forced to use other habitats (Sharpe, 2014). As a conservative measure releases in the range of 600 ML/day are not recommended during January to March in the Upper Yarra River due to the potential risk to platypus. This would not compromise the environmental objectives related to Australian Grayling (*Prototroctes maraena*) as the summer/autumn high flow of at least 1,300 ML/day that is required to provide a cue for migration and spawning and to transport larvae to the estuary and sea is recommended for the April to May period (see Sharpe *et al.,* 2012).

Conclusion

This investigation has demonstrated that a high flow release of 600 ML/day into the upper Yarra River did not have a major detrimental impact on ecological conditions. Consequently, to satisfy ecological objectives related to Australian Grayling, additional releases from the Upper Yarra Reservoir can be made without irreversible ecological impacts. However, consideration should be given to the timing of releases. For example, Sharpe (2014) states that there are risks to River Blackfish and juvenile platypus if high flows are released into the Upper Yarra River from late October to early March (Jacobs 2014). The 600 ML/day experimental release occurred during April and May in this investigation so different results may be found at other times of the year.

Sharpe (2014) also states that macroinvertebrate communities and fish populations may be able to recover from a single disturbance event, but are likely to be significantly affected by two or more moderate or high disturbances in the same year. The lack of change in macroinvertebrate communities associated with the 300 ML/day release and the 'interrupted recovery' of the community following the 600 ML/day release suggest the time period between releases should be considered. While the environmental flow recommendations stipulate the magnitude, frequency and timing of the releases, the timing between different components of the flow regime may need to be incorporated into environmental flow recommendations.

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