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Protecting our catchments to conserve biodiversity in rivers and streams

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Thanks very much for the opportunity to present to you, today. I'm going to present on a number of aspects to the research that I've been involved in over the last fifteen years or so, much of that close to the Strathbogie Ranges. The lessons that we've gained working on those systems and watching how they have been affected, particularly during drought periods, in terms of changes in their hydrology are very broadly applicable across, not just Central Victoria, but much broader parts of the inland. I'll present on some of the additional thinking we've done around what the lessons at that local scale might mean when we look at much broader landscape scales, as well.

Water storages and altered flow regimes

I have also done a lot of work on water issues in the Murray-Darling basin, mostly over the last ten years. When you look at how those water issues are discussed, not only in the broader media, but also in government, you might well get a sense that our river networks comprise the major streams and large in-stream dams. There is a huge focus on the management of water releases from storage and in those main stem river networks. And there is no doubt, if you look from a purely volumetric point of view, that's where many of the big problems are.

Having done a lot of work on small streams, an alternative representation of the river network shows all of the river networks right across the basin. While it's incredibly important that a strong focus of the water debate is around the main stem rivers and dams like Hume Weir, we have to make sure that we don't lose a sense of what some of the challenges and issues are in those more upland headwater regions.

I want to spend a bit of time talking about the smaller farm dams, of which there are many many thousands dotted across the landscape. They've been mapped quite well and, in some places, we actually now have not just good mapping of where they are at a point in time, but how they have been changing through time across the Murray-Darling basin. There's somewhere in the vicinity of half a million large off-channel dams. In addition, there are somewhere around between two and three hundred thousand small farm dams. Now, the definition of small farm dams varies between states but generally they are dams that can be constructed without significant barriers to the licensing. In terms of volumetric water use, they account for a really small fraction; less than 10% right across the basin.

One of the keys point is that, when we look at water recovery in the basin, that hugely costly process has done very little to address the impacts of these small dams, and I'll talk about what those impacts are in a moment. For now, it's worth pointing out that the impacts of small dams on inflows into the Murray-Darling basin are represented in all of that hydrologic work that is done. But, it's really the impacts of the inflows on the amount of water that winds up in those much larger storages that's being considered, rather than considering the impacts on these small headwater systems.

A few years ago we actually tried to estimate what the relative impact of different forms of water resource development was in terms of their spatial extent across the river networks of the basin (Bunn et al, 2014). We considered a whole range of different types of water resource development: bores that tap into groundwater; irrigation channels which distribute water across the landscape in irrigation areas; off-channel water storages such as those that I've just been discussing; and then the on-channel water storages, which are really the large dams in the system and those that are mapped and captured in a database. A huge fraction of the network is impacted by the small dams.

So, when we think about opportunities for conservation and protecting water-dependent species within the river network, managing these small dams effectively, or failure to manage them effectively, potentially has huge impacts.

Impact of storages on individual waterways

I turn now to what we understand about what those impacts are at a more local and sub-catchment scale. Castle Creek is a tributary of the Goulburn River. If you drive up the Hume Highway from Melbourne to Albury, Wodonga, you cross over it just south of Euroa.

It's a very narrow catchment. Rising in the Strathbogie Ranges to the south-east and north and west across the flood plains into the Goulburn River. From the map layer of all of the farm dams across the basin, we added farm dams to the map of Castle Creek. A lot of these dams are low down on the floodplain and have a much smaller impact on the river's hydrology than those in the headwaters.

We did some work with consulting firm Jacobs (who were SKM) at the time. They had a fantastic team of hydrologists and a lot of experience in modelling the impacts of these small dams on river hydrology. What that entails is understanding the capture of runoff across the landscape from rainfall - how those dams fill and spill, if you like. Because, when they're half full, particularly those on the channel, they stop the downstream flow of water. Once they fill up and start to spill, flows occur as they normally would. These dams tend to have the most profound impact is in parts of the landscape where small reductions or periods without rainfall can lead to significant evaporative losses and emptying of the dams. And that means a refilling phase which strongly influences the downstream hydrology.

The modelling by Jacobs produced a graph of the flow duration curve. The graph shows the percentage of time that flows exceed those different volumes under three different scenarios: without farm dams in the catchment; with farm dams in the catchment; and then what we think the hydrology might look like under a particular climate change scenario. The curves show that, historically there was more than a megalitre of water going downstream each day for roughly 80% of the time. Now, a megalitre a day is often a threshold that we'll use as an approximation of cease to flow, because it's very hard to actually quantify flows when you get down below that. Our understanding would be that Castle Creek was largely perennial. It would have still stopped flowing during drought periods, but not for particularly long periods, and pools within the river channel would've persisted.

With farm dams in that catchment, we now see a significant reduction in the period of time over which Castle Creek flows and that's reflected in our observations of the system. And, when we've talked to landowners there, these predictions make sense. If we add climate change impacts, the story does get a little bit worse, but not significantly so. Farm dams have done much of the damage in terms of maintaining the hydrology permanence of this system. And when we look at other streams in this region, the story is quite similar. It varies a bit: in larger streams like Sevens Creek (north of Castle Creek) there is more permanent flow and a larger catchment area, and the impacts of the farm dams tends to be smaller.

Impact on aquatic animals

We've done a lot of work on sampling populations of fish and invertebrates in these systems and understanding what happens to them during drought. And there's a myriad of small refuge water holes that all tend to sustain populations of aquatic biota during drought periods, but they are very small. In many instances, they're disconnected from groundwater, so they are dependent on surface runoff for maintaining the water holes. They have a limited persistence time. The changes that we make to the landscape and to runoff in that landscape changes has a direct influence on the numbers of these water holes that persist. And as these water holes are lost from the system, populations that depend on them become more and more fragmented and more and more isolated from one another.

And so we would expect that, as the water holes are lost, the risk to local populations within that isolated river system increases.

We've done modelling to try and understand the risks for a number of species in this particular creek system. What the modelling shows for us is that, in years when more than 50% of the stream dries out, populations tend to decline in abundance. In years when more than 50% of the stream stays wet, there's a net increase in the population. In dry years, So changes in the frequency of those wetting and drying events – particularly the different proportions of the stream that persist or dry out - can quickly start to tip the balance in the frequency in which populations are growing or declining in numbers. And when those play out over the long-term, you see an increase in risk of extinction.

There are a number of different fish species that live in this river system and they each have different requirements in terms of landscape connectivity.

Carp gudgeons are very widespread across the Murray Darling Basin. They used to be known as western carp gudgeons but there are, in fact, a number of species that are genetically distinct but difficult to tell apart. They have a fascinating genetic population structure, in which it appears that there's some very strange asexual reproduction that occurs within some individuals. They are not necessarily a species that captures people's imagination or attention, but are, nonetheless, incredibly different in terms of their biology. Carp gudgeon are very poor swimmers. They don't move around a lot and so they're highly dependent upon those isolated pools for their survival. And they actually breed during the summer low flow period. Those low-flow conditions are actually quite good for them, as long as there's enough habitat to persist in the landscape.

Another species in the Basin is the mountain galaxias. And again, there's been some recent changes in the taxonomy this species. They tend to move around in the river network quite a lot. We had an honours student who was doing surveys of the species and I got a frantic phone call right around the time when they'd gone out to do a whole lot of surveys and to collect some fish for some experiments they were doing in the lab. And they couldn't find any at some of the sites they'd been visiting and capturing them really regularly. These were sites down on the floodplain, and they just couldn't find any. They were quite panicked and I encouraged them to continue and go and visit some of their other sites. And what they discovered was that all of those fish that were normally down on the floodplain had moved up into the headwaters to breed. And so, whilst we often think of fish undertaking seasonal migrations for breeding in coastal systems - and there are coastal galaxiid species that do exactly that - we see the same behaviours occurring in these inland populations, as well.

In years of drought, when the rivers remain fragmented through their breeding season, they don't get access to those headwater areas where there's differences in substrate. They need hard, rocky substrates or vegetated substrates to lay their eggs. In years when that dry period coincides with their breeding, they do not get the opportunity to breed. So, there's a really critical dependency between the periodic connectivity of streams and movement of this particular species in the landscape.

The information we've generated from working on these isolated populations in places like Castle Creek has been really interesting in understanding how changes in hydrology influence those local populations.

When we start to think about the broader landscape, we also want to understand those critical areas where populations may be at greatest risk. In helping to guide the management of these systems, we need to know what aspects of the hydrologic regime need to be protected.

So we undertook some work a few years ago where we collected all of the records of fish populations from thousands of surveys that had been done over the years, right across Victoria. It's a huge amount of work that's been done through time and includes the many surveys that any one study might do, and the many surveys undertaken by universities or by government agencies in any one year. When you collate that data over a long period, it creates opportunities for looking at landscape scale patterns that can be really revealing. We also obtained a lot of other information from a fantastic database on climate, hydrology, land use and terrain that's been collated by a colleague from ANU, Janet Stein. (This is all publicly available information available from the internet as GIS layers.) This information can tell us a lot about the characteristics of individual rivers and we can link that information with the surveys of fish populations. We've done some similar work with macroinvertebrates, as well. We combined all that information to try and understand what the associations are between those landscape variables and where we do and don't find particular species.

Modelling the presence and absence data provide up with landscape scale maps of the distribution of fish. We are particularly interested in understanding what the impacts of both prolonged drought and climate change might be on distributions. And so, we combined those input layers of hydrology and climate, with some of the projections from climate forecasts to actually start to look at relative change (Bond et al, 2011).

To give you a sense of what comes from these models and what they reveal about the importance of hydrology, I will use the example of river blackfish. River blackfish are a species that has undergone significant contractions in its range. And, like the loss of platypus in South Australia during the millennium drought, I think blackfish essentially disappeared from South Australia, with perhaps the exception of one or two isolated populations which were translocated during that period because it was almost certain that they would go extinct. So, it is a species that appears to be highly sensitive to changes in hydrology. We used projections of their present-day distribution to predict those areas where they're most likely to be found. When we looked at their future projections, the models showed significant contractions in their predicted distribution. In Central Victoria, the loss of permanent flow appears to be a major risk factor in losing those populations.

We did some additional work looking at trying to identify those parts of the landscape that would, , identify those types of landscape that offered the greatest returns from a conservation perspective across all of the different fish species that we've done these models for. And then to ask the question: how might that change when we think about changes in climate? We often talk about the idea that we should be starting to plan now for climate change and start thinking about not just which areas we conserve, but what species we might plant in the riparian zone, and whether we should start to think about changing those, or the provenance of the seed stock or tube stock that we plant, perhaps thinking about sourcing that from a drier part of the landscape.

When we think at really broad scales, we often talk about things like latitudinal range shifts, or altitudinal range shifts in species. But, in fact, our modelling showed that some of those ideas about range shifts, at the latitudinal scale and the long altitudinal gradients, just didn't seem to play out. In fact, what we observed was that those areas that are currently the best habitat today, predominantly tended to be the places that looked like they would continue to be the best habitat in the future. So, rather than thinking about shifts in range, the modelling suggested that we should be focusing on those areas that are currently really high-quality habitats and continuing to protect those.

The reasons for that conclusion are several-fold. It probably, in part, does reflect some aspects of the way that we've undertaken this model. It's very difficult to confidently forecast how species might move in the landscape, so that presents a significant challenge to the models.

But when you look at where those really high-quality habitats are for native fishes, they're often quite distinctive spots in the landscape which have relatively unique features; you don't find the same combination of hydrology, and substrate type, and channel form elsewhere. And so, when you change the climate and change the hydrology, those areas that might present the right hydrologic conditions in the future don't have the same combinations of those other features that will be lost from the landscape. So, a lesson from the work is that, if we can identify areas that are really good now, we should absolutely be looking to protect those.

But, in terms of what that modelling showed us about the hydrology, they show some really strong patterns and demonstrate the extent to which the data really supports some of the assertions we're making about the importance of hydrology. For river blackfish, some of the variables that we looked at in the modelling were: the minimum annual temperature that occurs in that particular part of the landscape where those fish are occurring; whether or not they're in a coastal or an inland drainage; interannual variability in runoff (from one year to the next, as we go through in drought cycles, do we see big or small changes in the actual runoff patterns); the number of zero flow days. Going back to that loss of flow permanence that I showed in that initial plots of the impacts of farm dams on hydrology, what these lines represent is predicted change in the likelihood of finding river blackfish as you move along gradients. Or, in the case of coastal, you're either in a coastal catchment or you're not (in fact, you're more likely to find species in coastal catchments).

As you go into parts of the landscape where there's more interannual variability in runoff, there's a constant, but gradual, decline in the likelihood of finding blackfish. No sudden changes. But when you look at zero flow days, blackfish disappear very quickly in systems that don't have permanent or perennial flow. Once again, this shows that loss of permanent flow has profound impacts on the likelihood of finding a whole suite of species.

We do get platypus in some of these streams where we've done this work and some recent modelling that's been done from survey work around Melbourne has shown a very similar response in platypus populations; that flow permanence is a really important factor in their persistence. One of the things we observed during the drought in the Strathbogies was predation by foxes of platypus that were moving around and being caught in dry parts of the riverbed. And so, again, there's perhaps multiple ways in which this loss of aquatic habitat can impact on species, even those that can move across the land. I'm sure a similar story applies for things like turtles, as well.

We assessed the probabilities of distribution changes for a whole range of species under different climate change scenarios (low, medium and high) and also a step change scenario, which was the patterns of temperature and evaporation and runoff that we saw during the millennium drought. The millennium drought was perhaps a very good window into our future. It was not inconsistent with some of the more severe climate change forecasts. Increasingly, I feel we need to stop talking about climate change as something that's happening in the future and recognise it is actually happening now. These assessments show significant changes in the relative distribution of most fish species across the state under all of those different climate scenarios.

The message is that climate change is going to increase the need for us to think about how we manage some of those other threats that are already occurring in the landscape.

And, on that, I go back to farm dams and perhaps a demonstration of where that's working really effectively. The particular problem of farm dam impacts has been very well recognised in the Mount Lofty Ranges in South Australia for some time. A couple of years ago they ran a competition with a large very large prize for someone to develop a low-cost low-flow bypass structures. If we can pass some of the water that flows into farm dams downstream during those periods when water isn't actually spilling or seeping out of the dam, then many of their impacts can be mitigated. The technology and being able to retrofit it represents a challenge. They are now in the process of investing $12.1 million in installing low flow bypasses on farm dams in up to 500 locations in the Mount Lofty Ranges (see Securing flows in the Mount Lofty Ranges) It's a problem they have been trying to deal with in that region for a long time and they've found a technical solution. It's not necessarily a cheap one, but it's clear that without addressing that impact, the prospects for downstream conservation of flow-dependent species is very limited. So it's really exciting to see that, in this particular case, they've managed to garner the investment.

Tackling the impacts of these farm dams presents a really major opportunity to have a significant impact, not just on temporary conservation issues in headwater streams, but also in terms of how we can best deal with the additional impacts from climate change.

The last thing that I wanted to just finish on is, of course, that it's not just about water. I've emphasized hydrology and the role of hydrology in sustaining populations in headwater streams this morning, but we know, of course, that there are a range of other impacts that can also be managed effectively at the local scale. In particular, stock access that can have a profound impact on, not just water quality, but also the downstream systems including the small remnant water holes during dry periods. It's during dry periods when the impacts on those remnant pools become really strong and really severe. And, once again, there's clear options around providing off-stream watering to avoid stock having to congregate around isolated water holes and stream channels

Thanks.

Q	Thanks. I found that really interesting, particularly the low flow bypass. Obviously, there's a lot of farm dams and a lot of us have farm dams. What was going through my mind was how a lot of our streams used to be chains of ponds and we've lost that. And then, also, through compaction of the soil through our stocking, we've got a lot more surface flow. So, environmentally, there is a need for more ponds in the landscape. And then, also, in our property, we're surveying birds and we're finding the bird diversity is very dependent on the nearness of farm dams. So, it's a real challenge how to get the balance right here, given all the changes we've made to the landscape. What other opportunities are there to better integrate farm dams and could you also, perhaps, elaborate a little bit more on that bypass system, which sounds really interesting.

NB	Sure. Look, you're absolutely right. There's many dimensions to this of farm dams and what role they do and don't play in a positive sense, as well as a negative sense in the landscape. You're right in that, when we look at the changes in the landscape from a purely hydrologic perspective, we know that land clearing and the compaction of soils has probably increased total runoff. And so, when you look a lot of the straight hydrologic modelling, it would actually suggest that flow permanence or the amount of runoff has increased. And yet, for people that have lived on the land for a long time or you look at early records from settlers and explorers, water was really prevalent in the landscape. There were many systems that were chains of ponds.

And so, there's actually a challenge in trying to reconcile some of these different lines of thinking. The total yield has potentially gone up from land clearing, and yet we see much less permanent water in the landscape today. And I think that's probably due to a couple of things. One is that farm dams have altered runoff during particular periods, by capturing water higher up in the landscape. At the same time, we've also changed river channels in many ways, such that they're far less retentive, as well.

So, we've removed, in many instances, a lot of the vegetation and wood from river channels that helped retain water in those systems. In many channels, they've been infilled with sediment as well, so that pools that were once much deeper are not as deep as they used to be. And then, we've also reduced the groundwater. In many instances, groundwater perhaps played a greater role historically than it does today, particularly in floodplain areas, in helping sustain some of those remnant pools. So, there's a lot of things going on that are important in terms of understanding that hydrologic story.

So can farm dams play a positive role, I think the answer is yes, for some. For example, if they're managed in a way that protects some of the structure of the fringing vegetation on at least some of their margins, then, potentially, they can be a valuable point of water in the landscape for amphibians and that sort. So they certainly do have some biodiversity value. The problem is on the river channels, and particularly where they dams are on river channels in headwaters, where they don't have that same connectivity. So, the downstream barrier is very rarely overtopping and so a series of farm dams down the river channel, whilst it may have some appearance of almost being like a chain of ponds, it's a chain of ponds that's very rarely physically connected through overtopping. So, that's one of the issues for dams that are actually physically on the channel.

These are all things that can be managed without having to necessarily entirely remove dams from the landscape and that's where the low flow bypasses come in, as a really nice solution. I can't actually tell you much, to be honest, about the solutions. Even just a very small solar pump coupled with a sensor that captures either changes in water levels or during rainfall could be installed over the top of an existing dam. It just transfers some of the additional water, that's captured during those brief wet period or during a period of increasing water depths, into the downstream system.

Q The regulations on farm dams came in about fifteen years ago, restricting on-stream dam construction for anything more than about a sixty-hectare catchment. That may have restricted the number of new dams being put in, but we've got more and more people moving into rural areas, particularly in Central Victoria, who are also wanting dams. Do you know what the net result of those two factors is on the number of farm dams?

NB Yes. I think you're right, that there's certainly been restrictions placed on on-channel dams. There's a lot of debate and that debate's gone so far as, in many instances, going to court, as to actually what is a river channel. And geomorphologists can debate that for a long time. So, there's certainly depressions, if you like, or drainage lines where a series of farm dams will still have a big impact on the downstream flux of water, even though they may no longer be on what we might define as a river channel. I was involved in a court case many years ago where a dam was constructed on a river channel. It wasn't a small farm dam; it was a large one and it did breach the licensing. But, it was one of those situations where, unfortunately, it's hard to compel someone to remove something that once they built illegally and so, in that instance, no changes were enforced.

The changes in demographics are factored in many parts of the state. There's a downsizing in properties and, as you say, when there's subdivisions, there's a driver to potentially put another dam. That's a really interesting aspect of the change in how we're managing the landscape and I think there's probably very varying degrees to which individual landholders do actually or don't depend on the dams that they have on their property, as well. So, it's very hard to make blanket statements about best way to deal with the impact.

Q I substitute the word fair to another four letter word, but we always seem to fair the farmers. The mining industry automatically seems to get licensed for huge water consumption and, personally, I feel that could be better used to support our arable land.

NB I don't disagree and I certainly don't want to create the sense that I'm singling out farm dams over other aspects of water resource management that equally need attention. I think what's interesting about farm dams is that, as the Mount Lofty examples demonstrate, there are solutions that can be effective in mitigating the downstream impacts on hydrology, whilst not massively impacting upon the utility of the dam on the property. I think it's one of those situations where we can almost have our cake and eat it too - if we're prepared to spend half a million dollars on installing low flow bypasses, I might add. So, it doesn't come for free, but there are options available.

Q Nick, is the opposite situation true, thanks to urbanisation, where you put too much water into a stream? Like, it's cold water and too fresh. Is that something you've looked at?

NB Yes, we have. I've been doing some work close to Melbourne. Melbourne Water manage the catchments around Melbourne. About a third of the landscape that they manage is agricultural, but quickly being urbanised. For example, around Wallan, literally at the divide of the Murray-Darling basin, there's urbanisation occurring right in the headwaters of Merri Creek. And the impacts of urbanisation are profound, in terms of the changes in hydrology. There's a similar issue around the loss of flow permanence because, in the same way as we talk about soil compaction, urban areas expedite the runoff of water from the landscape.

If the water from things like roads and roofs isn't just transferred via storm water pipes into streams, you very quickly see a loss of recharge of groundwater and, also, very rapid, very high flashy flow regimes. So, in urban systems, the big challenge is how do we retain more water in the landscape, in the right parts of the landscape, in ways that can sustain all of the processes that depend on it.

Q [Inaudible].

NB Melbourne Water is certainly very concerned about the impacts of hydrologic changes on the downstream receiving systems. They spend huge amounts of money in some of their downstream areas and they recognise that this investment is being compromised by failure to manage impacts further upstream - and that's both impacts of farmland and impacts of urbanisation in some of the rural growth corridors. Working out how to try and manage stream systems with this huge rate of urban expansion is big challenge. Sadly, one we are losing at the moment.

Q You were concentrating on small farm dams. We are living right next to a small drinking water reservoir for a small town in our area and we are always concerned about the environmental flow. Is there some sort of legislation that the reservoir people (in our case, it's Western Water), that they have to provide us with environmental flow? We have been sampling fish, we have got the galaxias, the southern pygmy perch and sixty-odd little macroinvertebrate critters. So, we are very concerned about the environmental flow.

NB State government Catchment Management Authorities right across the state invest a lot of effort in determining downstream flow requirements from dams that are managed for various forms of water supply. There are some instances that I am aware of, where the ability to release water from storages is limited and that can be a factor that limits the ability to implement a flow regime. But I absolutely agree with you that it's really important that we're managing flow regimes below these larger dams just to support the flow variability that supports population processes and other ecological processes occurring in the river. If it's not happening in your case, the question I'd be asking is why not.

Q There was an issue, locally, about an environmental flow regime in the Mount Cole Creek and a reservoir topping it. And who would be the first port of call you'd go to talk to about trying to release more water to get a creek flowing that has been badly affected by the raising of a dam wall in that reservoir?

NB Most likely the CMA. They would generally at least understand what the background's been and they're often very involved in the management of water downstream from storage.

References

Bond, N. R., Thomson, J., Reich, P., and Stein, J. A. 2011. Using species distribution models to infer potential climate change-induced range shifts of freshwater fish in south-eastern Australia. Marine and Freshwater Research 62, 1043–1061. doi:10.1071/MF10286. See here.

Bunn et al. 2014. Environmental Water Cluster. CSIRO Water for a Healthy Country Flagship, Australia. See here.