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ORIGINAL PAPER

Planning for the Murray-Darling Basin: lessons from transboundary basins around the world

Caroline A. Sullivan

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Abstract Water does not recognise political boundaries. Almost all countries of the world (that are not island states) share rivers, lakes, groundwater or wetlands. Indeed in many cases, rivers and lakes form the border between countries. Just as importantly, water bodies crossing within-country provincial or state boundaries, as in the case of the Murray-Darling Basin, can give rise to disagreements in the ways water is shared and used. Even at a local scale, water systems often run across the territories of different cultural or ethnic groups, where demands from livestock and arable farmers may conflict with the needs of communities or water intensive industries. In the case of the Murray-Darling Basin, the situation of multiple demands is intense. Not only is the basin the traditional food bowl for the Nation, it is also the source of water supplies for hundreds of municipalities and regional centres, as well as providing for the demands of the 1.3 million people who live outside the basin in the nearby city of Adelaide. As a result of the complexity of river basin management, the idea of Integrated Water Resources Management has been something that many governments (including Australia) have been committed to for many years, and indeed, Australia and the Murray-Darling Basin has long been held up as a key example for others to follow. Recent pressures within that basin however have given rise to a wide variety of disputes around the way water is allocated, and attempts to develop an effective integrated plan have not been as successful as previously hoped. In this paper, the challenges of managing transboundary basins are examined, putting the debate around the Murray-Darling Basin Plan into a global context.

Keywords Murray-Darling Basin · Catchment management · Water conflict · Integrated Water Resources Management (IWRM) · Transboundary river basins · Adaptive water management

1 Introduction

As a single continent, Australia is in the unique position of being able to manage its water resources, without the need to consider international relations. Being a federal nation, however, means that the country is made up of independent states, each with its own parliament, and each with its own identity and set of values. Within this context, the Murray-Darling Basin provides an interesting example of a river where a number of different independent jurisdictions are in place to control its waters. As a result, the challenges it faces are often reflections of what can be seen in other major rivers, where the waters cross international boundaries, yet need to be managed as a linked and integrated system.

Being one of the larger rivers of the world, the Murray-Darling is made up of two large river systems (the Murray and the Darling, both of which are over 2,000 km in length), and their very many significant tributaries. Covering over 1 million km^2, the basin is located in the South Eastern part of the Australian continent, and includes a portion of four states and the Australian Capital Territory (ACT), as shown in Fig. 1. In terms of area, 56.6 % of the

C. A. Sullivan (✉)
Environmental Economics and Policy, School of Environment, Science and Engineering, Southern Cross University, Lismore, NSW, Australia
e-mail: caroline.sullivan@scu.edu.au

C. A. Sullivan
Marine Ecology Research Centre, Southern Cross University, Lismore, NSW, Australia

basin is in New South Wales, with 24.5 % being part of Queensland. In the South, Victoria accounts for 12.3 %, and South Australia for 6.4 % of the basin area. The whole of the ACT is within the basin, but this only accounts for 0.2 % of its land area. This is further complicated by the fact that not only does the basin come under the control of these different states and the ACT, but also management of land and water across the basin is influenced by the very many local government jurisdictions that fall within the catchment boundary.

Over the long history of its development since the arrival of Europeans, the Murray and Darling rivers have provided many income generating activities from their solid ecological base. With the topography lending itself perfectly to flood irrigation techniques, it quickly became the heart of modern Australian agricultural production. Cash crops such as cotton and rice rapidly became established, and provided a healthy income stream for farmers, before international competition became an obstruction to that progress. Water use efficiency was not an issue of concern, with water being a relatively low-cost input. As a result, water for irrigation today takes up 75 % of the mean annual volume of the basin (Tan et al. 2012). While this river has provided food security for humans for many thousands of years before the arrival of the Europeans, the development of irrigation infrastructure over the last several decades has given rise to major threats to freshwater-dependent habitats, riparian vegetation, and many local species (Mooney and Tan 2012).

Today, over 2 million people live in the basin itself, and the City of Adelaide, although outside the basin but near the river mouth, also uses the water for its municipal and other needs. In terms of water withdrawals, the largest portion (51 %) is used in New South Wales, with Victoria using some 34 % of total withdrawals. Ironically both the upper and lower parts of the basin (Queensland and South Australia) each use just 7 % of withdrawals, and ACT uses 0.3 %.

The challenges faced by water managers in the Murray-Darling Basin are found in many places of the world where water flows across socio-political boundaries. In most cases, these transboundary rivers cross international boundaries, or even form these boundaries themselves. Across the world, there are some 261 rivers which are shared by 2 or more countries, and there are many more rivers on every continent which are shared between regions and states within countries themselves. Some 3 billion people today live in international river basins, which

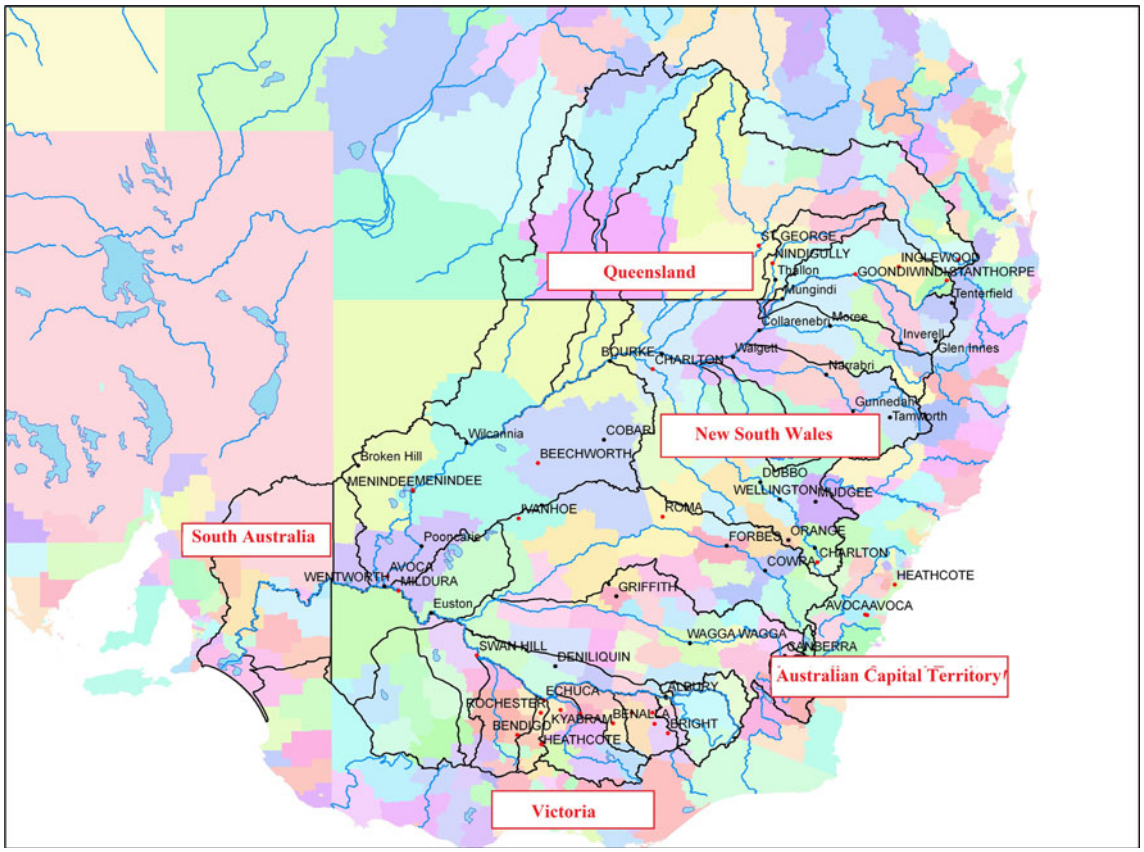

Fig. 1 The complex state and local jurisdictions of the Murray-Darling Basin

together cover some 50 % of the Earth's land surface, and account for about 60 % of total freshwater flows. Recent work has shown that the majority of this freshwater flow in the world's rivers already faces some measure of degradation (Vörösmarty et al. 2010), and the impacts of climate change are likely to make this worse in the future (Bellie and Christakos 2011; Sullivan and Huntingford 2009).

In many of these shared basins, people are already facing serious conditions of water stress, a condition highlighted recently by McClain (2013). These include several examples from sub-Saharan Africa, North East Brazil, Southern Europe, South and Western parts of the USA, the Middle East, and many parts of China, India and Australia. As a result, in addition to limited access to domestic water supplies, many millions of people suffer from an increased risk of reduced food security, and many millions of farmers struggle under increased burdens of debt. At first sight, reasonable and equitable sharing of available water seems an obvious solution in situations of water stress. However, in practice, there are many obstacles to this, including entrenched positions over issues such as historical rights, cultural values and political persuasions.

In relation to water use for irrigation, in many countries, particularly in rural India, water conflicts arise widely as a result of wealthy farmers digging ever deeper wells and using ever stronger pumps to take water from the dwindling aquifers hundreds, or even thousands of feet below. In other areas, pollution from both industrial and agricultural activities reduces water quality, bringing about degradation of aquatic ecosystems, and loss of ecosystem services with potential health impacts for both humans and livestock, as well as on habitats and biodiversity.

This is a particularly difficult problem in situations where regulatory frameworks are weak or non-existent, if there is a low enforcement capacity in local institutions, or simply a lack of consensus about principles and ethical values underpinning water governance and management (Bark et al. 2012). Another common problem found in large river basins is the number of institutions involved in water management. These often give rise to intractable problems between institutions not wanting to give up their existing power base. All of these factors give rise to major inequalities in access to water, or in control of water sources. In many cases, this results in citizen defencelessness, and the weakening of rights-based institutional arrangements.

In addition to sharing water for its own use, there are also issues arising over the use of river water for power generation, or navigation. Misuse of water, giving rise to problems of transboundary water pollution, is a major issue in many parts of the world. Water conflicts can arise as a result of natural disruptions to the hydrological cycle, most commonly, when these disruptions are characterised by drought. While in many places people do work together in the face of extreme events, this is not always the case. Indeed anecdotal evidence suggests that cooperation is more explicit in response to flooding, while drought brings about more competitive behaviour (for scarce resources).

At the local scale, if water shortages become extremely severe, strong individuals often take action to get what they need. This can be seen daily across the world at domestic access water points, when strong young men push into queues displacing women waiting patiently to get water. In East Africa, nomadic herdsmen struggling to find water for their cattle have been known to break pipelines which they perceive to be taking their water from traditional springs. In urban areas, rising water utility costs often leads to an increase in illegal water connections, reducing hydraulic pressure and disrupting the normal distribution processes, leading to increased costs. In extreme cases, as has been noted in Bolivia, disagreements about water sharing can generate intense political and social unrest.

The purpose of this paper is to discuss the multifaceted characteristics of river basins, and highlight the need to address these in an integrated way across national and international jurisdictions. In particular, attention is drawn to the fact that challenges in international transboundary basins are often reflected in river basins crossing borders at any scale.

2 Human impacts on river systems

While humans have been influencing the world's rivers for millennia, the concurrent processes of industrialisation and demographic change over the last 200 years have had the gravest of effects on rivers on every continent. While the impact of water diversions for human use has long been known, only recently has an attempt been made to consider the cumulative impact of this and other diverse threats to freshwater systems. In a global analysis published in *Nature* (Vörösmarty et al. 2010), a total of 23 geospatial drivers were assessed within a topographically integrated global grid model, providing an insight into the state of river health for all major river systems across the world, as illustrated for Australia in Fig. 2.

Map A in Fig. 2 shows that threats to water infrastructure and investment, there is no evidence of high level threats to human water security anywhere within Australia. When we look at threats to freshwater biodiversity, however, the situation is different. In Map B, we can clearly see the impact of human actions in the Murray-Darling Basin (darker grid squares in the SE of Australia), indicating a high level of human induced threats to freshwater ecosystems.

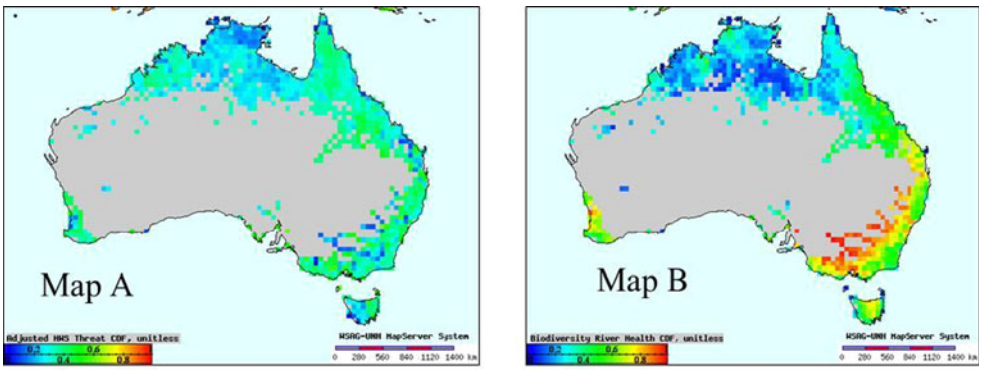

Fig. 2 Demonstrating the impact of basin infrastructure: *River Threats* in the MDB

Adjusted human water security (Map A) is achieved as a result of investing in water control infrastructure. The impact on freshwater biodiversity (Map B), is however, severe.
Source: Vorosmarty et al, (2010), data from www.riverthreat.net

3 Moderating human impacts: rights versus responsibilities

This demonstration of human impacts on river systems highlights the importance of whole basin management. The issue of how water can be managed equitably between us, in all of our competing demands, within a legal framework, is still something which is urgently needed (Sullivan and O'Keeffe 2011), but remains a challenge. Since 805 AD, there have been some 3,600 treaties agreed over water sharing, but in spite of all these efforts, we are still far from getting a full international ratification of the 1997 UN *Convention on the Law of the Non-Navigational Uses of International Watercourses.* At all institutional scales, water law in all its complexities is far from complete. This is due to the fact that we lack adequate information, which must inevitably come from a variety of sources. We also often lack adequate institutional arrangements, or appropriate administrative skills, and most frequently of all, there may be a lack of political and commercial will.

While the Human Right to water has finally been recognized in 2010 (United Nations 2010), there are still huge gaps in the way water allocations are made and the ways such rights may be implemented. A globally accepted form of international water law is still largely nonexistent, and the UN *Convention on the Law of Non Navigational use of International Water Courses* has still not been ratified into law due to lack of signatories. Even the recently developed UN Water Convention (UNECE 2013) has a long way to go before it will impact on transboundary basin activities in all parts of the world.

There are however many forms of water law at the local, state and federal levels in most countries, but these are highly heterogeneous, resulting in inadequate legal protection. For example, many instances of water law only relate to surface water (although 50 % of drinking water for humans comes from groundwater), and often these are completely inadequate at addressing the complexities of ill-defined resources such as wetlands (Sullivan and Fisher 2011).

According to the Global Water Partnership, water governance is the "*range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services*". From a political point of view, governance involves the determination of what objectives and values are pertinent, and what means are chosen to achieve these. According to Hanf and Jansen (1998) governance has to do with '*shaping and sustaining the arrangements of authority and power within which actors make decisions and frame policies that are binding on individual and collective actors within different territorial bounds (state, county, municipality,* etc.)'.

In reality, political processes are essentially a matter of power relations, often characterised by frequent confrontation between rival political actors. Governance and citizenship are key to these wider political processes, and conflicting views must be taken into account by fostering cooperation (UNESCO 2006; Bellie 2011). By bringing together the scientific and technological community with the social actors of the relevant political processes, there is a greater likelihood that institutional arrangements in relation to water governance can be created to produce a more equitable ecologically and socially sustainable outcome.

The use of concepts such as 'governance', 'citizenship' or 'civil society' presupposes the existence of a shared understanding. The meaning of these concepts is however both historically determined and subject to socio-cultural and political specificities. For instance, 'civil society' or

'citizenship' emerged from specific historical processes that took place in Western Europe and the USA, and still reflect rival intellectual and political traditions. In less developed parts of the world, or places where different world views are in place, these concepts are either weak or non-existent, casting doubt on the potential for river basin plans to be effectively implemented.

Another dimension of water governance that has arisen in recent decades is the provisions for privatization of water utilities. This process of water privatization has given rise to many social and political conflicts. From the 1980s, urban water conflicts have increased, and in the metropolitan area of Mexico City, for example, this continues to be an ongoing problem. In all continents of the world, there are many examples of tension arising over conflicting models of governance and unrealistic expectations from local populations with rival sets of values, principles, and normative preferences. To date, across the world, there has been no widely accepted solution about how the costs of water delivery can be best covered in the light of rising demand for services and dwindling budgets to supply them.

4 The importance of valuation of water resources and their associated ecosystems

Without effective means of valuing the environmental impact of our actions, little progress can be made to operationalize truly effective *sustainable* development. Like any other resource, water must be valued economically if economic instruments are to be used in its management. Several methods exist which attempt to capture environmental values, but there is little consensus on best practice. A pragmatic approach based on adjusted use-values may be needed, until the science of environmental valuation is much improved.

Within the context of river basin management, there are many aspects to be considered which cannot be assessed using normal financial appraisal. These may include things like the value of biodiversity loss when habitats are destroyed, or loss of human welfare resulting from changes in land use (for example, through pollution etc.). To ensure that decisions are made in an equitable way, generating effective sustainable outcomes, it is essential to incorporate all values which are currently unaccounted for. A range of valuation techniques can be used to try to achieve this, but there are many values associated with water management which are simply beyond monetary valuation. Novel approaches are needed to address this gap.

Within the Murray-Darling Basin, this issue of how water for its different uses should be valued is a very important concern. If degraded riparian ecosystems are to be restored and retained, water must be allocated directly to them to support *environmental use*. To many, this represents a trade-off from what are perceived as more economically productive uses, such as agriculture. It is important to note however that degradation of the ecological integrity of the river itself will have serious long term impacts, not only for agriculture, but also for other possible income generating activities such as recreational fisheries, bird-watching and other forms of tourism.

5 The need for water sharing

River basin development inevitably influences people throughout the basin, and to ensure equitable and rational decisions are made about water allocation, a holistic perspective of the whole basin must be taken. Widespread uptake of an *Integrated Water Resources Management* (IWRM) approach goes back to the international acceptance of the *Dublin Principles* in 1992. These provide a firm basis on which water resources should be managed to reduce water stress and other water related problems. The four Dublin Principles relate to the hydrological cycle and the finite nature of freshwater, the need to manage water in a participatory manner, recognition that women must play a central role in water management, and recognition of the value of water as an economic good. Acceptance of these principles has been an important step forward in the achievement of the UN agreement on the establishment of IWRM as a way to manage large river systems (UN-Water 2008), and billions of dollars have been spent to achieve this.

The implications of this approach are that land and water across a basin are inexorably linked, and must be managed as a whole. While this is easily demonstrable in theory, in practice, the reality of achieving IWRM is far from clear (Biswas 2008). The multifaceted challenges that must be addressed when attempting to manage whole river basins are found in many diverse river systems across the world. Table 1 provides some insights into key challenges in large transboundary basins, and suggests some measures that can be put in place to address these. Inspection of this table indicates the degree to which the Murray-Darling system is influenced by the same kinds of problems as many other large *multinational* river basins across the world.

The Murray-Darling Basin is clearly not alone in facing conflicts over water allocations. Sharing of water between different groups in society, and the environment, can be a very contentious issue (Wallace et al. 2003). Throughout the world, conflicts regularly occur between neighboring farmers, or between communities who may have conflicting interests over water use. Such conflicts may arise between different social or ethnic groups, different

Table 1 Transboundary river basins: management challenges and actions

Challenge	Examples where action is needed*	Potential policy and Management Action
Droughts and floods	Murray-Darling, Rhine, Danube, Brahmaputra, Mekong, Bravo-Grande	Effective and accurate assessment and monitoring, better integrated hydroclimatic modelling and adaptive management
Water pollution	Elbe, Tiza, Jordan, the Mekong, Tigris-Euphrates, Murray-Darling	Economic instruments, enforceable regulation, basin institutional development
Allocation of water rights	Murray-Darling, Colorado, Bravo-Grande, Mountain Aquifer (Palestine/Israel)	Institutional strengthening, identification of property rights, and removal of free-riders. Potential for cultural and ethnic conflicts likely
Hydropower generation	Senegal, Mekong, Congo, Columbia, Colorado	Full cost assessment to include any loss of environmental and ecosystem goods and services, or loss in terms of human health. Potential for benefit sharing but transmission losses are an issue
Maintenance of ecological integrity	Murray-Darling. All	Need to assess environmental flow requirements, need for water allocation to support ecosystems
Food security	Ganges, Senegal, Guadiana, Nile, Orange, Tigris-Euphrates, Murray-Darling	Removal of market distortions, potential for mutual benefits from virtual water trade and benefit sharing
Lack of awareness	Murray-Darling. All	More open and transparent debate on the distribution of benefits of current and potential water sharing practices. Need for public awareness raising
Climate change	Murray-Darling, Indus, Ganges, Brahmaputra, Nile, Thames	More accurate, finer resolution climate data are needed, along with integrated hydro-climatic models linked more closely to water and human actions. Adaptive water management meeds tp be implemented at a variety of scales

* These are just a few examples of the better known cases, but these problems are widespread across almost all basins in the world

municipalities, between different economic sectors, between counties or provinces, or even between nation states who have shared surface or ground water resources.

Due to the nature of hydrology being such that water flows downhill, it would be reasonable to assume that upstream water users may have better access to resources than those downstream, and that actions of upstream users are likely to impact on those downstream. While this is indeed almost always true, it is also true that downstream uses can impact on upstream users. At the transboundary scale, how downstream users may impact on upstream communities can be illustrated by the unusual example of the Orange-Senqu river basin, in Southern Africa, where the downstream country (South Africa) has established an agreement with Lesotho (the upstream country), over water storage (Sullivan et al. 2010). Under this scheme (the Lesotho Highlands Water Scheme), South African water security is met through water stored in a series of very large reservoirs in the Lesotho Highlands, which is then transferred in a timely manner through a huge transboundary grid, to ensure water is delivered to the industrial powerhouse of Johannesburg.

While this agreement is said to supply some 40 % of the GNP of Lesotho, it also has impacts in terms of ecological change, and population displacement. The *Lesotho Highlands Development Authority* is tasked with channeling these water-generated funds (from South Africa), to useful and productive development activities in Lesotho itself. These and other downstream interests are addressed by the *Orange River Basin Commission* (ORASECOM), which includes Botswana and Namibia who are the other downstream riparian states. Like the Murray-Darling Basin Authority, negotiations between riparian states must be carried out, and decisions made over complex water sharing arrangements. Unlike the Orange Senqu basin however, policy failure in the Murray-Darling is fortunately unlikely to give rise to starvation or an increase in child mortality rates, as it often does in Sub-Saharan Africa.

A more local scale illustration of downstream-upstream impacts in water sharing arrangements is provided by the example of island communities dependent on cruise tourism. In these cases (for example in Grenada and other Caribbean islands), when water is uploaded to cruise ships, water pressure in marginal municipal areas upstream becomes so low that communities often cannot access it.

6 Addressing water conflicts

How water resources can be shared is a complex question. It may be that a simple agreement can be made on taking turns in water access or use. This kind of approach has worked well in traditional communities (for example in Bali, Indonesia), where some kind of social mores and standards have become accepted as a way of managing water sharing. In other situations, de facto tacit agreements have been made whereby competing users adjust their behaviour to take account of the needs of others. In yet further situations, people simply agree to take their turn, and as long as the community regulates this by preventing domination or

unfair practices, this can work relatively effectively. In many cases, however, the complexity of the situation requires more formal agreements to be made, in some places in the form of by-laws, or in others in the form of legally binding arrangements. More recently, water markets have evolved as another tool to support water sharing.

In all of these many and diverse situations, a solution has to be found to enable users to have access to the water resources they require for both economic growth and basic survival. If this does not happen, then inevitably, conflicts occur. As human populations have risen, and the use of water has become more explicitly tied to economic development, the matter has become more urgent, resulting in a greater potential for conflict.

In relation to global food security, recognition of the potential impacts of climate change are also exacerbating this concern, with the IPCC warning that crop yields on rain-fed lands in African river basins may be reduced by as much as 50 %, with the grain belts of North America, Asia and Australia likely to be similarly impacted. Indeed, in the Murray-Darling Basin itself, potential changes in the availability of rainfall have been highlighted (Chiew et al. 2011), while the sharing of these depleting water resources is also likely to give rise to serious future conflict (Jiang and Grafton 2012).

7 Addressing water sharing in the Murray-Darling Basin

At just over 1 million square Kilometres in area, the Murray-Darling Basin (MDB), covers 14 % of the landmass of Australia. Some 64 % of Australia's irrigated land is in the basin, but this actually uses 95 % of the total water withdrawals for irrigation in the whole country. Containing some 30,000 wetlands, of which 16 are listed under the *Ramsar Convention*, the southern part of the basin in particular provides major water storage across the vast floodplain. The many native fish, birds and mammals specific to the basin (including many of which are endangered), are economically and culturally important, while being heavily dependent on the river's highly variable, erratic flows (Australian Conservation Foundation 2012).

Throughout the history of the continent, the Murray-Darling Basin has played an important role. In pre-European times, the rich bounty of the huge river drew different Aboriginal groups to its waters, shores and wetlands. Gradually at first after European settlement, and then with greater speed, the basin soon became developed to the point that agricultural water users managed water flows for the benefit of increased yields to farmers, and economic development for the nation as a whole (Tan et al. 2012). This widespread industrial-scale agricultural development across the basin brought consequences unanticipated at the time, and resulted in major changes in the natural flow regime of the river (Le blanc et al. 2012).

By the 1990s, the basin's ecological and hydrological health began to be questioned. Threats on the basin's capacity to deliver water led to recognition that the river had to be managed more holistically. With international uptake of the principles of Integrated Water Resources Management (IWRM) simultaneously occurring, it was quickly realised that a more integrated approach to managing the water in the MDB was clearly needed. With four powerful states and the Australian Capital Territory all making some claim on the river, as well as the hundreds of local government areas within them, it was recognised there was clearly a need for some kind of federal level of basin management. As a result, the Murray-Darling Basin Commission was formed, and in 2008, this was streamlined to become the Murray-Darling Basin Authority (MDBA 2012). Like many other transboundary basin authorities, the MDBA has had to address major water allocation decisions across all these many social and political boundaries.

Frequent drying of the Murray mouth has been repeatedly identified as a potential symptom of the anthropogenic modification of river flows, and underlying mis-management of the basin. Several authors have suggested that the basin is in a poor state of ecological health (Kingsford et al. 1999; Leslie 2001; Humphries et al. 1999; WWF 2010; Rogers and Paton 2009), with some stating that as many as 95 % of all species in the MDB are threatened (Le blanc et al. 2012). Another example of ecological concern is manifested by increases in terrestrial plant species cover at the Macquarie Marshes and Barmah-Millewa Forest (CSIRO 2008). However, in spite of these ecological concerns, farmers depending on irrigation continued to resist water allocation change. When the newly designed Murray-Darling Basin plan was first released for public consultation late on a Friday afternoon in 2011, panic and chaos were widespread among farmers across the basin.

8 The objectives of the Murray-Darling Basin Plan

The overall objective of any river basin plan is to reduce conflict and secure a future for the river. The Murray-Darling Basin plan is no exception to this. This gave the *Murray-Darling Basin Authority* the responsibility for developing a new Basin Plan, for its enforcement, and for the establishment of the Authority as the *Commonwealth Water Holder*, ensuring optimal river health. In implementing the Plan, the Authority has to take account of where the environmental water is most needed, and in what volumes.

Since the upper Murray-Darling has little capacity to significantly affect flows using dams (MDBA 2011), most of the diverted water recovered will be from the southern basin, where over-allocation is also more significant (Crossman and Overton 2011), and where ecosystem health is deemed very low. According to the 2008 amendment to the Water Act (Govt of Australia 2007, 2008), the MDBA's Basin Plan must determine the long term average *Sustainable Diversion Limits* (SDLs), to reflect an environmentally sustainable level of take for the Basin's surface-water and groundwater resources. *Key Ecosystem Functions* (KEFs) such as sediment loads, nutrients, carbon exchange, habitat maintenance and connectivity (Falkner et al. 2009) will need to be monitored to ensure compliance with the objectives of the plan.

For individual sub-basins, environmental watering plans must be established, along with water quality and salinity plans. The framework and rules for transferable water rights through a water market must be clarified, with water 'buy-backs' being strictly made on the basis of "*willing seller, willing buyer*" agreements. In addition to these ecological concerns, the socio-economic impact on specific basin communities have to be considered within this basin plan, even though it has been recognised that such legislative action suggested in the plan may make some of these unviable (Garrick et al. 2009).

In comparing the situation in the Murray-Darling Basin to other transboundary basins, it is important to note one major difference, and this is the issue of population density. While millions of people earn their livelihoods in the Murray-Darling Basin this number is small relative to its geographical size, particularly when compared with populations in other major transboundary basins across the world. Nevertheless, while it is clear that agreements for transboundary basins must be tailor-made for each specific set of circumstances, an examination of these circumstances can provide some important lessons to be learned.

9 Lessons for water sharing from other transboundary basins

The challenges of transboundary water management are so complex that by necessity, they must be tackled by a multidisciplinary team capable of dealing with the problem from all its angles. It must consider issues from local, municipal, state and national perspectives. A politically appointed federal representation by diplomats or politicians will not be adequate to address the inherent complexity of the water allocation problem, in all its competing uses. Inputs from a range of different stakeholders are needed if effective infrastructure or policy development is to be achieved.

For example, from the case of the Rio Bravo-Grande basin on the Mexico/US border, it is evident that equitable water sharing must take account of the different levels of development in different parts of the basin. Furthermore, if different laws or other institutional arrangements are in place in different parts of the basin, the development of basin-wide management strategies is difficult (Sullivan and Fisher 2011).

The case of the Indus Basin is also of relevance to the Murray-Darling Basin. In this case, where the interests of both Pakistan and India come to the fore, several problematic issues in water sharing continue to delay progress. Not only are there problems about sharing the water between countries, but also there are many problems within Pakistan itself about how the river waters are shared between its own states, with the downstream riparian states complaining bitterly that upstream states are taking too much, impacting on the Delta region. This is very similar to the situation in the Murray-Darling, as state level agreements must form the core of any basin agreements, and the reduction of flows to the lower lakes has threatened the Ramsar status of the estuarine wetlands.

As in the Murray-Darling Basin, the Danube river basin has seen major hydromorphological changes over the past hundred years. Such changes include the building of dams, weirs and sluices, the canalisation of rivers, their disconnection from floodplains, and the erosion of the river beds and lowering of water tables. In both the Danube and the Murray-Darling, these changes have consequently brought about higher flood risk, and several major floods have occurred there, as well as in many other basins across the world. To make matters worse, under the *European Water Framework Directive*, (European Community 2000) large areas of the Danube basin are classed as '*heavily modified*', and have failed to reach the '*good ecological status*' now required by that Pan-European legislation. This also reflects the degraded wetlands across the Murray-Darling, where in many areas, forests of iconic wetland Red Gums trees are under threat.

In S.E. Asia, the Mekong basin drains a huge area, incorporating major parts of several large countries including Thailand, Vietnam, Cambodia, Myanmar and Laos. Intensive rice production and industrialisation in many parts of the basin have contributed to both point and diffuse sources of pollution creating serious cumulative downstream transboundary effects, with freshwater and coastal fisheries heavily impacted. Coupled with this, urban runoff and poorly managed municipal wastewater have the effect of increasing water treatment costs. In 2000 and 2001, millions of people were affected by floods across several of the riparian countries of the Mekong basin, with major rural infrastructure impacted, and millions of livelihoods disrupted. The frequency and intensity of floods, especially in low lying areas and the delta, are expected to increase as a result of climate change, and indeed large

scale floods have been recorded on several occasions in recent years. As a result, flood mitigation and climate adaptation are now high political priorities for international cooperation within the basin.

The formation of the Mekong Basin Commission in 1995 was an important starting point in this process of international cooperation, but initially this river basin commission did not include China, or Myanmar, making it ineffective as a representative body for the whole basin. While some antagonism exists over China's impact on the flows in the Mekong River, the need for cooperation to support economic development has been recognised, and today, many cooperative projects are in place, on power generation, telecommunications, tourism and transport. The lessons learned from the activities of the Mekong Basin Commission are useful for other transboundary basins, as it provides some good examples of how transboundary river agreements need to be broadened to incorporate environmental protection and human resource development, as well as building cooperation on regional economic progress (Fox and Sneddon 2007). This is clearly a lesson of relevance in the Murray-Darling Basin, as these two issues have become the most problematic when developing agreements about how the Australian basin can be managed.

The importance of designing a basin plan with inclusive consultation and shared values has been highlighted in a number of parts of the world. For example, the Senegal River covers parts of four countries in West Africa, all of whom require water from the river for various sectors, including hydro-power generation, irrigated agriculture, municipal water supply and industry. The Senegal River Basin Authority, OMVS, is one of the earliest river basin authorities to be established, and since 1972, this has provided a useful model for river basin management and allocation of water for benefit sharing in riparian countries. The case of the Senegal river provides an excellent demonstration of how the sharing of benefits, such as hydropower and navigation, can be as important as sharing of the water itself, and a river basin authority can provide a good instrument for collaborative development of infrastructure to manage water resources.

A number of other transboundary basins across the world have many lessons for river basin management. In the Nile Basin for example, there is little doubt that the intensity of international engagement in the basin through the *Nile Basin Initiative* (NBI) is a direct result of the legacy of previous legislation of the waters of the Nile, dating back to the 1920s. If the basic rule of water sharing based on '*equitable and reasonable use*' is to be implemented for the 160 million people in this transboundary basin, it is important to develop and agree upon a clear understanding of what this term actually means for each partner country.

A second major lesson from the Nile Basin Initiative is that while 'soft' water solutions (Gleick 2002) have played an important role during this fostering of cooperation, 'hard' solutions are what is actually wanted by the people of the region, if more equitable benefit sharing is to be achieved. In the case of the Nile, this relates to the development of power infrastructure to support the distribution of energy generated from Nile waters, under the NBI *Nile Basin Regional Power Trade Project* (part of the Shared Vision Plan for the Nile). The message from this is that the *recognition of the rights of all riparian stakeholders* is essential, if effective sharing of the benefits of water resources are to be peacefully achieved.

While international efforts to develop a cooperative approach in the Nile Basin have been successful to some extent, recent actions by various riparian countries are now attempting to improve their own benefits from the Nile. While both Egypt and Sudan have historic rights over the Nile waters, other upsteam countries such as Ethiopia are now trying to capture what they see as their share of its benefits. As the then Ethiopian Prime Minister, Meles Zenawi, argued in 2010: "*The current regime cannot be sustained. It's being sustained because of the diplomatic clout of Egypt. There will come a time when the people of east Africa and Ethiopia will become too desperate to care about these diplomatic niceties. Then, they are going to act*" (The Columbus Dispatch, 29 May 2010). This is supported by the fact that the majority of the upper Nile riparian states signed a *Cooperative Framework Agreement* in May 2010, although Egypt and Sudan put up a strong opposition to it. Unfortunately this indicates that there now appears to be some fragmentation of the cooperative approach achieved early on through the Nile Basin Initiative. The message from this is that the *recognition of the rights of all riparian stakeholders* is essential, if effective sharing of the benefits of water resources are to be peacefully achieved. This is an important lesson both for the Murray-Darling Basin, and for the future political integrity of Australia as a whole.

The importance of the cumulative effect of stressor impacts in large river basins have been clearly demonstrated by Vörösmarty et al. (2010), and there is no doubt that Integrated Water Resource Management is really needed if we are to address the major threats to global freshwater systems. When considering the lessons learned from major international basins, it is certainly worthwhile to think about how these can help strengthen water decision making in basins where boundaries may be within one country, but nevertheless cover large areas where jurisdictions and regulations vary considerably.

10 Trade-offs and property rights in integrated land and water management strategies

Trade-offs are an inevitable part of economic decision-making and resource allocation. When populations are growing, and economic demands on water are also on the increase, water for other purposes (such as for the environment), becomes less available. Decisions need to be made about what has to be given up if more water is allocated to urban areas, or to support a specific form of agriculture. Since the economic returns from different water uses vary considerably, there is a need to reassess the priorities given to these different uses.

When water is allocated to irrigation rather than natural wetlands for example, it is important to consider who are *the winners* and who are *the losers*, with this consideration being made over both short and long time frames. In a situation such as in the Murray-Darling Basin, the development of water markets has been used as a mechanism to drive water redistribution. While this works for some users and sectors, it does not work for others, and the whole issue of property rights over both land and water must take account not only of the direct users, but also of the indirect impact of that use. If water markets are to work as a mechanism to support water allocation across the world, both land and water property rights must be clearly determined (Qureshi et al. 2009), and appropriate legal frameworks must be established to support these (Schulz 2007).

Property rights for water can be categorised in three ways. *High security of supply*, indicating priority in allocations, *Low security of supply* is based on lower volumes from less certain sources, and the lowest level of water security is from *state-of-nature based claim*s for water (depending on current storage and rainfall). The advantage of such a classification system is that in management decisions, water delivery can be raised in some areas, and lowered in others (Sennett et al. 2012). Water entitlements can be used as long-term permits to receive a certain allocation of water, with this amount influenced by inter-annual variability and other factors (Freebairn and Quiggin 2006).

Within the Murray-Darling Basin, water sharing plans have become more sophisticated, and the need for appropriate frameworks to address potential conflicts has been recognised (McKay 2011). On a more operational level, examples of how institutional arrangements can be drawn up to facilitate more effective processes of water sharing include the *Waterworks Amendment Act* of 2003, which requires farmers, or other users of river water, to pay a River Murray Levy otherwise known as the *Save the Murray Fund* (Government of South Australia 2012; New South Wales Government Department of Environment and Heritage 2011). Furthermore, there is also the capacity for farmers to exit the water delivery system all together, by selling their water entitlements, ideally at a higher price than they paid for them (Sennett et al. 2012). In the long run this has important potential to reduce agricultural water demand, or redirect its use to more productive activities. In this case, what is considered *productive*, must be determined through a consultative social process.

The use of market-based instruments (MBIs) has been applied to support water policy in several countries, based on *polluter pays* and *basic needs* principles. In the form of subsidies or taxes, these can play an important role both as a deterrent and an incentive. In the Murray-Darling Basin, it is important that the four states and the ACT can agree on the levels of subsidy that should be provided for the various measures to be applied. Unless there is a need to raise revenue for a specific purpose, fiscal measures to support water management should ideally be budget neutral, but all measures must be applied in a transparent and equitable manner across the basin.

There is no doubt that water markets have an important role to play in addressing water allocations under the increasing conditions of water stress currently being experienced in most transboundary basins. To support this, it is essential that accurate and effective systems of water accounting be introduced at the earliest opportunity. In any transboundary basin, the reliability and acceptability of the appropriate data on which policy measures are based, often acts as a constraint on the efficiency of fiscal policy measures. This can often be a stumbling block, either through legacy arrangements of data collection in different countries or states, or through deliberate mis-reporting for political or strategic reasons. To move beyond this difficulty, we must make full use of the latest digital technology to implement internationally recognised systems of water accounting, both similar to, and aligned with, the UN System of National Accounts (UN 1993). This process of developing water accounts is now evolving under the auspices of the Australian Bureau of Meteorology, but how these can be explicitly linked to the financial accounting system remains to be determined.

11 Can compensation schemes work?

Markets and market-based instruments can provide a basis for the development of compensation schemes. Within river basins, these often relate to *upstream-downstream* impacts, or *benefit sharing* schemes built into basin management arrangements. For this to function effectively there must be a flow of financial resources generated from those who benefit from improved basin management, to those who may need to make sacrifices. This principle can be applicable at any scale from households to nations. In

the case of the Murray-Darling Basin, this is implemented through the process by which some water users will give up their entitlements as '*willing sellers*', to others who require more water, as '*willing buyers*'. While this arrangement, according to market theory, will theoretically ensure that water is used in the most efficient way, there may often be conditions in which sellers perhaps decide to sell their water entitlements as a result of social and cultural reasons, rather than economic ones. For example, this may be the case with small rural and regional communities within the basin which become untenable as out-migration reduces the supply of farm labour, and existing farmers move into retirement. With these conditions existing in the Murray-Darling Basin, it is important to recognise the need to move beyond purely economic market-based instruments when implementing water allocation decisions.

If compensation schemes are to work and be accepted by all stakeholders, there must be a clear and recognised link between the actions of one group (e.g. upstream land users) and the impacts on another group within the basin (e.g. downstream drinks manufacturers, or municipalities). The impacts felt by these downstream communities must be quantifiable, and there must be a way to assign values to them. This continues to be a major challenge, and ever more sophisticated approaches are considered to have some merit (Chen et al. 2005). When a group of basin water users benefit from a reduction in these upstream impacts, they must be committed to making a payment for the resulting improved conditions downstream. When practices such as upstream-downstream compensation schemes are implemented, compensation will be paid to those in the basin who take action to make improvements. Often this is the result of a group effort (whole community) and thus the compensation should be paid to the group as a whole (e.g. to a group of residents in a subcatchment, or members of a farming community who take action together to change water use). While such arrangements are often complex and bureaucratic, there is a clear role for such compensation schemes in multifunctional shared river basins.

12 Discussion

Humans are not by nature altruistic. They are competitive, as demonstrated by our acceptance of the idea of the *survival of the fittest*. To further add to the complexity of the water management challenge facing people in transboundary basins, humans are also highly dependent on natural ecosystems for their own life support. While the human ego may like to believe that he can control the environment as a sub-system of his economy, in the grand scheme of things, this is patently untrue. If human societies of any description are to continue sustainably into the future, they must learn rather rapidly how to cooperate and share water in transboundary basins.

It could be said that equitable and sustainable development in transboundary basins is almost an unachievable goal. It requires people and societies of diverse ethnic and cultural backgrounds to agree on the priorities and values associated with water management and use. The fact that the UN 1997 UN Convention on the Law of International Watercourses has yet to be ratified, demonstrates the difficulties in reaching international agreements such as this, even those that are not legally binding. While the more recently introduced UN Water Convention (UNECE 2013) is taking this issue forward, it is still very much work in progress, and there remains a massive gap in the institutional arrangements for water sharing at the international scale. This also illustrates why such agreements are difficult within the Murray-Darling Basin, even though the institutional boundaries are of a *state* rather than *national* scale.

In spite of these huge challenges, however, the need to work towards sustainable water management must still be paramount. All societies must have adequate water access for '*equitable and reasonable use*', but how they may define such a concept can vary considerably from place to place. From the many examples of river basin management already in place, there are important lessons to be learnt. The most important of these lessons, demonstrated from around the world, is that genuine stakeholder engagement is a necessary (but not sufficient) condition for success. Paying proper attention to detail in terms of building societal buy-in of basin agreements must be accepted by all engaged in the process of developing basin management institutions.

This has been evident in the case of the Senegal basin, where a decade or more of progress in the achievement of peaceful sharing arrangements has overcome many of the traumas faced in earlier times. As one of the oldest basin authorities in the world, Senegal's OMVS has managed to make headway, even under difficult hydrological and socio-cultural conditions. It is interesting to note that the name used for the river basin authority in francophone countries is *L'Organisation pour la Mise en Valeur du Fleuve (Senegal)*, which literally translated means an *organisation for putting a value on the flow* (of the Senegal river). This description goes straight to the heart of the matter of water sharing: reconciling values for alternative and competing uses. To a large extent, in the Senegal river basin, this has been achieved through the sharing of benefits from the river itself as power generation, and from the sharing of water for livelihoods and life support.

Human population density is a major factor influencing the challenges of water management. When millions of people need to allocate scarce water resources, economics is the science we may turn to, rather than hydrology. If this

is a core mechanism to address these river basin challenges, we need to become much more sophisticated in how we evaluate the benefits and tradeoffs which will inevitably result. To bring about the changes in human behaviour necessary for achieving a sustainable future in any transboundary basin, e*nforcement, persuasion, coercion*, and *moral obligation* are the tools we can use. While market-based instruments have a contribution to make as tools of transboundary water management, much more could possibly be made through *persuasion* and *moral obligation*. Perhaps it's time we start to learn more from the psychology of commercial advertising, and consider its relevance in the context of complex and difficult socio-ecological decisions, such as those required in all transboundary basins.

13 Conclusion

Australia has always been, and will always be, a place of extremes, and the extreme event calendar in 2012 and 2013 has been very full indeed. Being such an important resource to the nation as a whole, the Murray-Darling Basin has received attention from policy makers for many decades, and extreme events are recognised as core to its natural regime. The long history of data collection and hydrological modelling has built much capacity and public understanding of basin issues. The existence of this strong diverse database also provides an understanding of baseline conditions on which *critical thresholds* can be based. In an attempt to improve the management of the nation's major river basin through the use of this improved scientific data, the first draft of the Murray-Darling Basin plan was released in 2011.

While there is no doubt that this first version of this basin plan provided some useful insights, without adequate stakeholder consultation, vivid scenes were recorded in towns all across the basin, where otherwise law-abiding residents and farmers confronted government minsters. Scenes of angry irrigators burning the plan, while abusing basin bureaucrats, were flashed in media coverage across the world. Eventually, in late 2012 the final version of the plan was released, a compromise for all involved, with little real support from any quarter. It was almost with poetic irony, however, that the release of the final version of this plan, (largely developed to address water shortages) coincided with large floods moving for months down through the basin, hugely contrasting with the previous long period of dry weather now known as the *Millennium Drought*. Farmers and landholders had little time to think about complex policy documents when they were faced by weeks of destroyed crops, flooded pasture and stranded livestock.

The challenge of balancing water for economic use and water for the environment has been a core issue underpinning stakeholder views in the MDB for many years. In addition, the need to very explicitly take account of social, economic and cultural factors across the basin became obvious during the eventual more comprehensive consultation process. As in any transboundary basin, only if this is done properly is there likely to be successful uptake of the policy recommendations and implementation measures needed to bring about peaceful behavioural change.

Managing transboundary basins on any scale is a challenge faced in almost every country in the World. Being a single country in a whole continent, Australia does have the good fortune that it is not required to share its waters with other nations, but it does still have to consider this water sharing between its different states. In the Murray-Darling Basin, to address the need to reorganise water sharing, the Murray-Darling Basin Authority have attempted to design a basin plan that allows for flexibility and growth. It provides the means by which current water holders can either use or sell their water holdings. It recognises the need to secure the basin's ecosystems, and it acknowledges the importance of socio-cultural considerations. It provides the framework for this to be implemented, and it allows for adjustments to be made in the future, when better evidence of what is needed will come to the fore.

Nevertheless, in spite of this progress, due to both scientific uncertainty, and political positioning, exact measurements of how much water should be abstracted from both ground and surface sources has yet to be agreed on by all parties. This is most certainly still 'work in progress'. However, the monitoring processes and administrative flexibility that has now been built into the system, has the potential to allow for future changes in both hydro-meteorological conditions, and socio-economic values. Hopefully this adaptive management approach will support the continued development of more effective ways of managing this most important Australian transboundary basin. Such an adaptive approach to water management is essential in all transboundary basins, if an equitable and peaceful future is to evolve in this pressurised era of the Anthropocene.

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