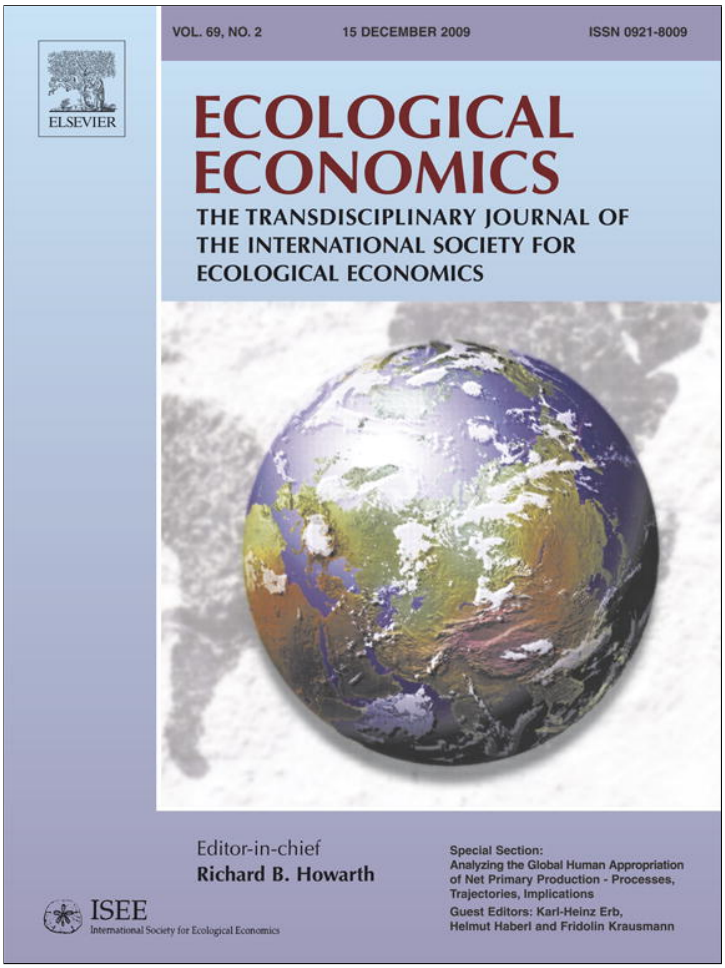

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Analysis

Water markets and freshwater ecosystem services: Policy reform and implementation in the Columbia and Murray-Darling Basins

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ABSTRACT

Water markets have featured prominently in the reallocation of water rights to restore freshwater ecosystem health. Incentive-based water rights acquisition and transactions have emerged as a market-oriented policy approach to reallocate water resources from existing uses to enhance the provision, regulation, and sustainability of freshwater ecosystem services. This paper develops a conceptual framework to examine factors enabling and constraining successful policy reform and implementation in market-based environmental water allocation. This analysis distills and extends the findings and lessons of a September 2007 workshop in Brisbane, Australia on environmental water transactions. Two case studies were selected in water stressed basins – the Columbia (U.S.A) and Murray-Darling (Australia) Basins – where transactional approaches to environmental water allocation first emerged. The case studies draw upon practitioner perspectives and previous policy and economic analysis in two regions where shared political economic and physical conditions lend a strong analytical basis for comparison. A common set of policy and regulatory reforms has occurred in both cases – albeit in different forms and via distinct paths – to develop three enabling conditions: (1) establishment of rights to and limits on freshwater extraction and alteration; (2) recognition of the environment as a legitimate water use; and (3) authority to transfer existing water rights to an environmental purpose. However, these elements of policy reform are necessary but not sufficient for effective implementation; a second set of driving forces, barriers, and adaptations explains the ability to achieve larger scale ecological outcomes. These conditions include the physical, social and economic factors driving demand for environmental water allocation; administrative procedures, organizational development and institutional capacity to effect transfers; and adaptive mechanisms to overcome legal, cultural, economic, and environmental barriers. The case study analysis suggests that environmental water transactions can play an important role in establishing environmental water allocations, although water markets require ongoing institutional capacity and adaptive governance. The conceptual framework and empirical lessons generated through this cross-case comparison provide the basis for an expanded research agenda to evaluate the design and performance of market-oriented reforms as implementation experience accrues and new programs emerge in diverse ecological and political economic settings.

1. Introduction

Providing freshwater for human development has led to increasing levels of extraction and hydrological alteration. These trends have impaired long-term ecological health in many river basins by disrupting the regime of streamflows that sustains fish and wildlife, ecosystem functions and, ultimately, human well-being and economic development. Notwithstanding intensified competition for freshwater, environmental and ecosystem needs have attained increasing legitimacy in the context of water's inherent variability and forecasts for less reliable river flows and water allocations in many river basins due to climate variability and change (Bates et al., 2008; Van Dijk et al., 2006). No longer strictly a matter of freshwater biodiversity, the integrity and resilience of freshwater ecosystems have become an issue of direct economic and social consequence due to the goods and services generated by functioning rivers, wetlands, and aquifers (Daily 1996; Postel and Richter, 2003; Brisbane Declaration 2007; Poff et al., 2009).

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Rising demands for environmental water supplies present a challenge to prevailing institutional arrangements governing freshwater access and use, especially in basins and regions already experiencing water stress. In response to growing water scarcity, views have shifted to recognize water's complex character as an economic good (Bauer, 2004; Hanemann, 2006). Such shifts have prompted interest in market mechanisms to allocate water for direct human uses and ecosystem needs, involving transfers of established water rights between willing buyers and sellers based on an agreed price. Consequently, market approaches to sustain or restore freshwater ecosystem services have advanced steadily in some contexts, particularly within the Columbia River and Murray-Darling Basins in the Western U.S.A. and South East Australia, respectively. As policy reforms and implementation efforts mature and begin to spread beyond these regions, scholars and practitioners have become interested in the underlying institutional arrangements and enabling conditions of these approaches as well as their transferability across different sociopolitical and physical contexts (Aylward et al., 2005; Horne et al., 2008). However, efforts to reallocate water from existing uses to environmental uses have prompted concerns about the equity implications of water markets, leading to the development of public interest standards, administrative oversight, and collaborative decision-making structures to prevent negative impacts from being concentrated on specific water user groups or local communities.

In this article, we develop and apply a conceptual framework to analyze two case studies of stressed river basins that have attempted to restore ecosystem health through incentive-driven water transfers. This framework helps to distill and build on the findings of a September 2007 workshop on environmental water transfers in Brisbane, Australia (Garrick et al., 2008). The Brisbane workshop pooled the expertise of fifty-five practitioners from six countries with a primary emphasis on the evolution and experience in programs within the Columbia and Murray-Darling Basins — two over-appropriated rivers where market-based approaches to allocate water for environmental flows first emerged. Panelists and participants discussed environmental water transactions along several dimensions, including enabling conditions, drivers, barriers, and adaptation strategies, based on the implementation experience in these two regions.

The paper is organized into three sections. The first section builds on previous policy research investigating the design and performance of market-based approaches to environmental policy and their application to the context of water allocation and environmental flows. This section incorporates prior economic and legal analysis to develop a conceptual framework that structures the case study analysis and comparisons. Case studies in the Columbia and Murray-Darling Basins are the subject of the second section, which comprises the empirical focus of the paper. The case studies first trace policy adoption in the two basins across several elements of reforms introduced in the conceptual framework. The second half of each case refines the set of enabling conditions and limiting factors by cataloging the drivers, barriers and adaptation strategies detailed in the literature and by practitioners at the Brisbane workshop. The third and final section offers a limited comparison of the cases by documenting crosscutting similarities and key differences between the institutional settings for market-based environmental water allocation in the two basins. This section concludes with a summary of cross-cutting similarities and differences between the cases, criteria for evaluating policy effectiveness, and directions for future research and policy analysis.

2. Conceptual background and analytical framework

The advent of markets and private property to govern access, use, and transfer of natural resources is neither novel nor recent (Hardin, 1968; Anderson and Leal, 2001; Thompson, 2000). An initial impetus behind market-oriented water allocation occurred within the context of the tragedy of the commons thesis and the notion that privatization or state control provided the best paths to avert overuse and collapse of shared resources like water (Hardin, 1968). Subsequent research identified a third type of resource governance based on cooperative, self governance of common pool resources (Ostrom, 1990), and the field of common pool resource governance lends useful insights to the analysis and evaluation of market-based programs (Tietenberg, 2002; Rose, 2002). The ensuing record of policy and institutional change has refined the core concepts behind market-based resource allocation and environmental restoration through practical experience.

In this paper, we analyze the cases by drawing on Tietenberg (2002) who identified four defining features of governance arrangements that rely on markets to privatize and allocate "commons" such as water supply, fisheries, and pollution emissions. First, market-based efforts must establish a limit on aggregate use of the resource, similar to the cap for a cap-and-trade system. Second, resource access and use are authorized through a system of private property rights to develop an initial allocation of rights, which may involve grandfathering existing uses. In the context of water allocation, the initial allocation is analogous to the prevailing system of water rights based on customary and formal rules (Meinzen-Dick and Bruns, 2000). The third element involves a mechanism to reallocate use-rights through incentive-based transfer processes, such as pricing signals or other economic incentives. The fourth feature relies on a system of administrative oversight for monitoring and regulating resource access, use and transfers. Common challenges to this model include controversy over the distribution of wealth associated with patterns of access and use, prevalence of negative externalities (external social and environmental impacts of private decisions), and high transaction costs in reallocation (Tietenberg, 2002).

Market-oriented policy approaches to satisfy environmental water needs are predicated upon the set of institutional reforms and preconditions outlined by Tietenberg (2002) and others (Anderson and Johnson, 1986; Colby, 1990a; Willey 1992; Siebert et al., 2000; Aylward, 2008a). Although distinct from the centralized command-and-control regulations adopted in the first wave of environmental policy in the 60s and 70s, market-oriented environmental policies depend equally upon strong institutions and governance regimes at multiple, nested scales, including well-defined water rights, transfer rules, and regulatory capacity for monitoring and enforcement.

Saliba and Bush (1987:1) defined water markets as the "interactions of actual or potential buyers and sellers over one or more interrelated water commodities." Such markets involve a set of transactions to reallocate water rights from lower to higher valued uses in response to changing pricing signals. In their dependence on price as a form of incentive-based allocation, such transactions are considered *voluntary* despite the political processes that produced the underlying regulatory framework and dictate its application on the ground. The concept of water markets emerged alongside a set of expected limitations known as market failures, which stem from water's distinctive physical and social interconnectedness as a marketed commodity (Bauer, 2004; Hanemann, 2006; Meinzen-Dick, 2007). Specific challenges include the potential for negative impacts on third parties, high information burdens and transaction costs, weak monitoring and enforcement capacity, and inadequate incentives for private contributions to maintain or restore the public goods afforded by freshwater ecosystem health.

Policy reforms that enable water markets to deliver environmental outcomes reflect an effort to redress market and institutional failures to supply water's publicly shared benefits at socially desired levels. As initially recognized by neoclassical economists (see Olson, 1965), resource allocation through market mechanisms will undersupply public goods dimensions of natural resource systems due to the tendency for individuals to free ride on the investments of others because individuals benefit regardless of their contributions to the provision of public goods. Therefore, market-oriented programs for environmental water allocation require coordinated, and often consensus-based or collaborative, efforts by public and private entities to assert and fund these environmental needs in the marketplace in order to achieve socially desired levels of water allocated for the maintenance or restoration of freshwater

ecosystem health (Anderson and Johnson, 1986; Colby, 1990a; Colby, 1990b; Aylward et al., 2005; Horne et al., 2008). For example, Colby (1990a) and Willey (1992) presented early evidence of the problematic public good qualities of water and the attendant need to recognize the environment as a legitimate use and authorize the public and private sectors, including conservation non-profits, to organize on behalf of environmental interests to acquire water rights for such purposes.

The analytical framework for this paper emphasizes the legal and regulatory reforms, as well as the ensuing drivers, barriers, and adaptive strategies, that enabled the emergence and growth of transactional approaches to reallocate water to the environment. As the conclusion cautions, however, other sociopolitical and physical contexts may entail different sets of conditions or outcomes. In so doing, this analysis draws closely on the analytical approach developed in the Millennium Ecosystem Assessment with its emphasis on drivers, tradeoffs, policy responses, and implementation barriers and opportunities (Aylward et al., 2005). Although the empirical material is derived from the panelists and commentary at the Brisbane workshop, the analysis rests equally on a synthesis and integration of legal and economic analysis and ongoing primary research and practice in the Columbia and Murray-Darling Basins.

3. Case studies

We present and evaluate the case studies in light of a set of factors deemed integral to the development of markets for environmental water. We separate these factors into two groups. *First*, there is a set of legal and regulatory reforms that enable markets:

1. establish rights to and limits on freshwater extraction and allocation
2. authorize the environment as a legitimate (beneficial) use
3. authorize transfer mechanisms to reallocate water for the environment.

In the absence of these reforms, reallocating freshwater to environmental purposes is infeasible (Aylward, 2008a). Alternative methods for satisfying environmental water needs can include compulsory reallocation of existing rights to an environmental purpose as a result of court decisions or administrative decrees, risking political backlash and conflict, as exemplified in the Klamath Basin water wars of 2001–2 (Doremus and Tarlock, 2008). The socio-political feasibility of coercive reallocation is limited (Slaughter and Wiener, 2007), although the history or threat of mandatory restrictions may exist alongside and motivate participation in incentive-based approaches (Thompson, 2000).

An assessment of environmental water needs occurs through an adaptive and iterative process of scientific research and multi-stakeholder decision-making. This process is embedded within each component of reform, especially during the establishment of the cap and legitimization of the environment as a water use. Competing methodologies have emerged for these purposes (Gillilan and Brown, 1997; Poff et al., 2009). The case studies included here, however, demonstrate that uncertainty about environmental flow requirements and a reliance on tentative, localized, or partial estimates of environmental water needs have not prevented efforts to reallocate water for critical priorities in areas already experiencing the environmental, social, and economic effects of overallocation.

The *second* set of factors includes the driving forces, barriers, and adaptations that enable and constrain implementation of environmental water transfers. The policy and regulatory reforms outlined above are therefore necessary but, on their own, insufficient to reallocate a single drop of "wet" water to environmental purposes, as exemplified by the 10-year lag between policy adoption and implementation in the Oregon Conserved Water Program, which was authorized by statute in 1987 but certified the first reallocation of water conserved through an irrigation efficiency project in 1997. Therefore, an additional set of conditions will determine the long-run prospects for reallocation and lead to feedback effects that may trigger additional policy and institutional adaptations. These factors include establishing (Dyson et al., 2003; Aylward et al., 2005; Aylward, 2008a)

- demand for environmental water through the allocation of public funds or the creation of incentive mechanisms that catalyze private investment.
- administrative procedures and organizational capacity to reallocate water rights, including institutional mechanisms to reduce the transaction costs and maximize the environmental outcomes of water transfers for environmental flows.
- planning procedures that set aside water for the environment before a consumptive pool is distributed for different entitlement types.
- governance mechanisms, including collaborative processes and institutions, to prevent or limit negative social and environmental impacts of reallocation.
- adequate regulatory capacity to monitor, enforce, and adapt to barriers and changing conditions.

The Columbia and Murray-Darling Basins provide ideal settings to examine and refine this set of enabling conditions and driving forces through the lens of practical experience. As the earliest and most extensive adopters of market-based approaches, these river basins represent the most advanced cases of market-based approaches to freshwater ecosystem services with over 20 years of policy reform and implementation. In addition to their common experience adopting and implementing market-based policy approaches to acquire water rights for environmental purposes, both basins share fundamental physical and sociopolitical conditions, including the prevalence of agricultural water use for irrigated agriculture in an arid setting, a system of private property rights to water, and a federalist governance structure with substantial authority vested in state governments. These shared conditions offer a strong analytical basis for comparison and limited generalization, although it is important to note that the Australian and U.S. contexts involve distinctive chronologies and patterns of policy reform, including a more punctuated set of policy changes in the Murray-Darling than the incremental multi-decadal process of reform in the Columbia.

4. Columbia Basin

The policy evolution behind market-based approaches to environmental water allocation in the Columbia Basin has involved three aspects adopted at multiple temporal and spatial scales and to varying degrees across the Basin:

1. The legitimization of environmental water uses under the beneficial use doctrine
2. The enabling of trading between existing rights and new environmental rights
3. The authorization and development of funding and organizational capacity to effect transfers for environmental restoration.

These reforms and polices are followed as we review the enabling conditions and driving forces underpinning the emergence of environmental water transactions in the Columbia Basin.

4.1. Enabling conditions

4.1.1. Limits (the cap)

A 1935 U.S. Supreme Court decision affirmed the 1877 Desert Lands Act to vest primary authority for water allocation at the state level (Gillilan and Brown, 1997; King, 2004). Contemporary water allocation institutions in the Columbia Basin have their legal basis in the doctrines of prior appropriation, beneficial use, and no harm — three principles that have taken hold in different forms in the arid and semi-arid states throughout the Western U.S. region (Sax et al., 2006). The prior appropriation doctrine upholds the "first in time as first in right" during shortages with the corollary that appropriators must

establish and maintain an authorized, or "beneficial," use without a prolonged interruption. Under this legal doctrine, the first person or organization to establish and maintain a beneficial water use is the last to lose access during times of inadequate supply. Changes to water rights cannot impose harm, or injury, on other users upstream and downstream. Therefore, the capping function noted by Tietenberg (2002) is accomplished implicitly through the physical limits of the river and the finite number of reliable, high security rights established by the first claimants to arrive (Aylward, 2008a). This allocation system rapidly enabled full appropriation of river flows before basin-wide closures began to occur through state statutory reforms, administrative rulemaking, or court adjudication. As early as the 1950s, fish and wildlife agencies assessed the minimum water needs for vulnerable fisheries. Yet, several watersheds in the Columbia Basin remain open to appropriations of surface water or groundwater. Increasing pressure on groundwater supplies has led to efforts to close watershed and require mitigation for new demands that impact hydrologically connected surface water (described below).

4.1.2. Environment as beneficial use

Legal and regulatory frameworks for water allocation initially strained to accommodate environmental values and water needs, although the Columbia Basin states were among the first where these emerging values resulted in statutory protections for rivers (Neuman et al., 2006). States in the Western U.S. and Columbia Basin began to recognize the environment as a legitimate water use under common law doctrines (such as the public trust), administrative rules that reserved unappropriated water supplies for instream flows, and, ultimately, statutory measures that authorized fish and wildlife as eligible "beneficial" uses for prior appropriation rights (Gillilan and Brown, 1997; Boyd, 2003; Charney, 2005). Several states in the Columbia Basin authorized the environment as a valid beneficial use for a water right after first reserving instream flows for fish and wildlife through administrative rules. For example, Oregon, Montana, and Washington first established programs to reserve water for minimum flow protection on priority streams for fish habitat in 1955, 1969, and 1967, respectively (Neuman and Chapman, 1999, Ferguson et al., 2006; Adelsman, 2003). Administrative reservations yielded limited conservation benefits in watersheds already suffering from chronically low flows and overallocation. Subsequent reforms strengthened the basis for establishing senior water rights for environmental purposes by authorizing fish, wildlife, and recreation as authorized beneficial uses. Thus, the limited benefits of administrative reservations led to statutory reforms to elevate environmental uses to the same status as other appropriative water rights (Pilz, 2006).

Legal recognition of environmental uses as valid beneficial uses occurred via two types of statutory reform: general water use statutes that acknowledged fish, wildlife, or recreation as beneficial uses and legislation targeted more narrowly on freshwater conservation goals. Washington and Montana provided examples of the first approach in which general water resource acts conferred legal recognition for instream flow as beneficial use in 1971 and 1973, respectively. Idaho and Oregon, on the other hand, passed special legislation targeting streamflow protection for fish and wildlife in 1978 and 1987 through the Minimum Stream Flow Act and Instream Water Rights Act, respectively. Federal influence on water allocation is limited to a nexus on federally owned lands, dam projects, and national environmental statutes, particularly the Endangered Species and Clean Water Acts. Consequently, vesting regulatory authority for water allocation at the state-level has created a complex patchwork of legislative and regulatory jurisdictions for restoring streamflows to conserve fish and wildlife. The primary legislative preconditions for market-based reallocation have developed unevenly throughout the Columbia Basin while remaining elusive for some Western states outside of the Basin (Charney, 2005).

4.1.3. Environmental transfers

A *second* set of water rights reforms enabled high priority rights to be leased or transferred instream without losing their underlying priority and reliability in Oregon (1987), Montana (1989), and Washington's Trust Water Program (1989–91) (Neuman and Chapman, 1999; Ferguson et al., 2006). In Idaho and Montana, initial legislative reforms authorized pilot programs that were refined, expanded, or extended permanently. Authority to pursue water rights transfers for environmental purposes raised governance issues to clarify which public and private entities were authorized and able to acquire, hold, and manage such rights to ensure the rights are maintained in the public trust for intended instream benefits. For example, while Idaho, Oregon and Washington require that state regulatory agencies hold and enforce water rights transferred or leased instream, Montana allows private entities to hold instream leases (Charney, 2005). More recently, private and public roles have begun to overlap and require greater coordination and accountability measures, leading to formal public–private partnerships between conservation buyers, regulators, funders, and sellers (see Washington's Water Acquisition Program, Adelsman, 2003, for an example). In other cases, private sector non-profit organizations have attempted to leverage public programs by engaging in or complementing planning, outreach, monitoring and enforcement activities traditionally led by state administrative agencies, especially in the common situation where regulation activity is primarily complaint-driven and state agencies face resource constraints that prevent proactive management of instream rights (Pilz, 2006; Garrick et al., 2008). As transactional activity has increased, rising administrative scrutiny of transfer, monitoring, and enforcement activities has created an institutional capacity burden in the non-profit and public sectors. For example, financing agencies have imposed stringent accountability measures on conservation buyers to require monitoring, and administrative agencies have enforced regulatory safeguards for third parties that can require time and extensive hydrological and legal analysis (Malloch, 2005; Pilz, 2006).

Contract types and transfer mechanisms take diverse forms governed by varying systems of rules and administrative procedures. The main contract types include permanent acquisitions, temporary leases, and the re-allocation of water conserved through irrigation efficiency projects (Loomis et al., 2003; Aylward, 2007; Hardner and Gullison, 2007; Garrick et al., 2008). Non-profit organizations often developed and tested emerging statutory authority for market mechanisms by participating in multi-stakeholder rulemaking efforts to interpret and apply administration procedures and regulations governing environmental water transfers. For example, the Oregon Water Trust was the first non-profit formed to acquire water rights to put into the public trust for fish habitat. As part of the Trust's organizational and strategic development participated in the rulemaking process for the state's instream leasing program to interpret and apply new authority for privately brokered environmental water transactions (Neuman and Chapman, 1999). Initially, transactional restoration efforts targeted tributary streams where small-scale acquisitions are an effective approach to restore connectivity and other ecological functions for flow-limited fish habitat; however, an increasing focus on scaling up and integrating solutions for larger restoration goals has emphasized the institutionalization of market-oriented transfer mechanisms, such as reverse auctions, water banking, and other sources of water, including regulated storage and mitigation for impacts of groundwater pumping on surface flows. A recent trend has involved growing reliance on forbearance agreements that temporarily or permanently reduce water use using contractual arrangements with private landowners. These agreements proceed outside of the formal process for administrative changes and transfers and provide a potential advantage by avoiding or minimizing administrative scrutiny. The advantages of skirting complex administrative procedures are counterbalanced by the inability to use forbearance agreements to protect water downstream of a diversion's historic point of return flow.

To summarize, the pattern of statutory and administrative reforms in the Columbia Basin warrants restatement in light of Tietenberg's set

of defining attributes to understand how enabling policy and regulatory reforms have developed (see Fig. 1 above). First, the prior appropriation doctrine establishes an implicit cap on water supplies, enforced through a priority-based allocation system. An administrative system upholds water rights and reinforces limits to freshwater extraction through monitoring and enforcement to regulate illegal water use during shortage according to the priorities established during the initial allocation. Statutory and regulatory changes recognized the environment as a valid purpose for a water right in the late 20th century and authorized transfers of existing rights to support environmental uses without losing their underlying priority and reliability. Despite these conditions, implementation experience reveals uneven authority and capacity to apply these formal laws and regulations on the ground.

4.2. Implementation drivers, barriers and adaptation

Implementation efforts offer insight into the factors shaping prospects for moving beyond policy reform to transfer existing water rights into environmental water allocations at the appropriate scale. Others have examined the ingredients for successful implementation through in-depth case studies in Oregon (Neuman and Chapman, 1999; Neuman, 2004; King, 2004), Montana (Ferguson et al., 2006); Washington (King, 2004), and the entire Columbia Basin (Horne et al., 2008; Hardner and Gullison, 2007). These studies catalog factors that facilitate implementation, including clearly defined water rights and regulatory mandates, financial incentives, collaborative partnerships, and strong scientific understanding to prioritize fish recovery efforts and thereby target demand for reallocation. Barriers to implementation stem from cultural, economic, or administrative resistance and poor information about water rights, third party impacts, or conservation priorities.

Based on the Brisbane exchange, factors affecting implementation can be categorized into driving forces and barriers. Adaptive learning and policy response to these drivers and barriers are central to success or failure, given the adaptive management framework that underpins restoration efforts in complex, adaptive ecosystems where information and feedback mechanisms are often understood and managed quasi-experimentally through a process of evaluation and institutional learning. The following section will examine drivers, barriers and adaptations in light of the material shared by practitioners from non-profits and agencies about their experience implementing environmental water transfers in different settings throughout the Columbia and Murray-Darling Basins.

4.2.1. Drivers

4.2.1.1. Demand drivers. The financial drivers of demand for market-based environmental water allocations are evolving rapidly in the Columbia Basin. These drivers are divided into two categories: salmon recovery and growing urban demand. Salmon fisheries define the region's culture, ecologically and economically. Their precipitous decline during the 20th century stems from several interacting natural and human factors, This decline, culminating with the listing of 13 evolutionarily significant populations of salmon and steelhead as threatened or endangered under the Federal Endangered Species Act, triggered a range of biological studies and recovery actions totaling over $2 billion by 2002 (GAO, 2002). More recently, indirect drivers of urbanization and associated land use changes are providing additional financial impetus for environmental water allocation through market transactions. For example, efforts in the Deschutes and Walla Walla Basins are driven in large part by new demands from residential developments in competition with existing agricultural and endangered species demands.

The financial drivers of environmental water demand echo a common theme regarding the importance of crisis for triggering policy response. Policy reforms have strengthened demand drivers for environmental water acquisition by generating regulatory mandates for fish habitat restoration and mitigation of new water demands for residential housing. Prominent examples include the expansion of statewide non-profit water trusts and other non-profit organizations defined at the basin scale, such as the Deschutes River Conservancy, which formed in 1996 along with federal authorization of funding. Government acquisition programs also emerged in the late 1990s. The Washington legislature launched a pilot acquisition program of 1 million dollars in 1999, for example, before expanding resources to $3.5 million for the 2001–3 biennium (Adelsman, 2003). Other state and quasi-federal programs for fish recovery followed, including the formation of the Columbia Basin Water Transactions Program (described below) in 2002 with an annual authorization of $4 million for acquisition and implementation expenses (CBWTP, 2004).

4.2.1.2. Institutional drivers. Institutional arrangements supporting market approaches to allocate water for environmental purposes in

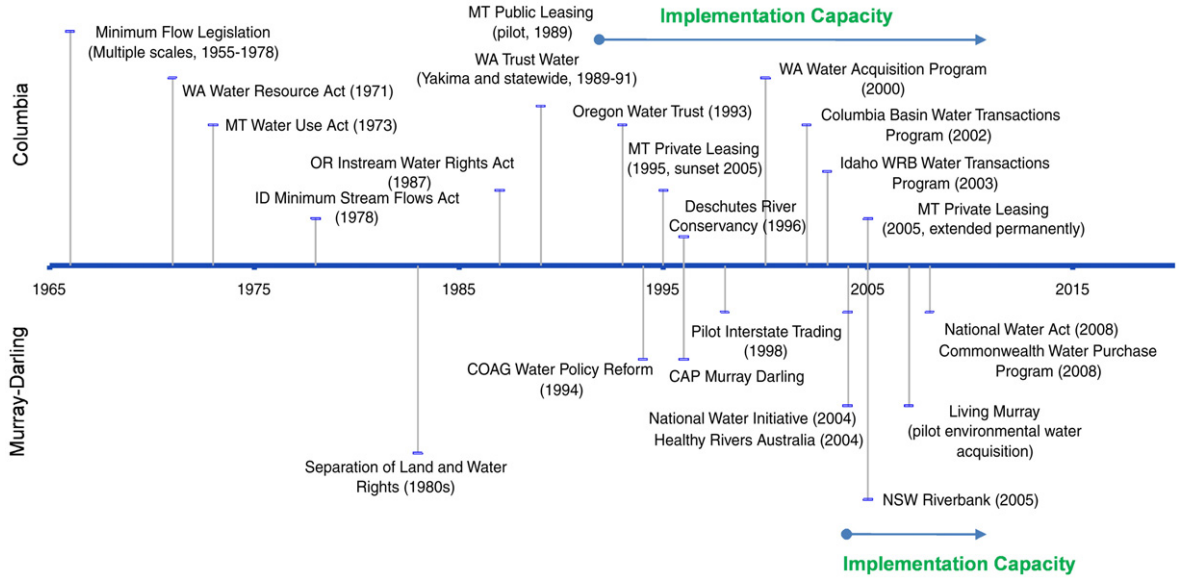

Fig. 1. Evolution of policy reform in market-based environmental water allocation (1955–2008).

the Columbia Basin developed first through state-level policy reforms and watershed-based planning efforts for instream flow programs (see above) before evolving into a Basin-wide framework. Without these public mandates and resources, voluntary provision of instream flows might otherwise fail to deliver adequate levels of restoration due to the free rider problem associated with public goods. Initially, in the mid 1990s, environmental water transfer efforts relied on non-profit organizations to organize on behalf of environmental water needs and develop financial resources from both private donors and then-nascent public programs tied to the recovery of endangered salmon fisheries.

The Northwest Power Act of 1980 is a point of departure in the evolution of a coordinated basin-wide program. The Act called for attention to fish and wildlife conservation in association with management of the hydropower system and created an interstate council to address this need. The Council formed a fish and wildlife program in 1982, and the listing of salmon and steelhead as threatened and endangered under the Endangered Species Act in 1993 lent additional urgency to habitat recovery. In 2000, the Northwest Power and Conservation Council Fish and Wildlife Program passed its fifth revision of the Fish and Wildlife Program and the National Marine Fisheries Service released its biological opinion to guide salmon recovery efforts under the federal Endangered Species Act. These two events converged to lay the groundwork for a coordinated program of land and water acquisitions. Provisions contained within these two documents provided the basis for the establishment of the Columbia Basin Water Transactions Program — a coordinated, Basin-wide environmental water transfer program administered by the National Fish and Wildlife Foundation in partnership with the Bonneville Power Administration and the Northwest Power and Conservation Council (NPCC, 2000; NMFS, 2000).

4.2.2. Barriers

Barriers to market-oriented environmental water allocation stem from several sources in the Columbia Basin, including cultural, economic, legal, and environmental factors.

4.2.2.1. Cultural. In Brisbane, practitioners from Montana and Oregon detailed cultural barriers in developing transactions, highlighting the need to gain trust with landowners by spending time to: develop relationships, communicate about the scientific importance for acquisitions, and pursue short-term leases or "seed" deals to build toward longer-term or larger scale transactional activity. Cultural stigmas and economic impacts associated with fallowing productive agricultural land have led to programs to restore streamflows through transactions acquiring water conserved through irrigation efficiency projects and changing points of diversion and place of use, allowing farming to continue while enhancing instream flows. Trout Unlimited's restoration project on Poorman Creek in Western Montana is an example of an irrigation efficiency project that offered a win–win scenario for farmers and fish by allocating the water conserved to augment instream flows without reducing agricultural productivity. However, panelists in Brisbane emphasized the hydrological and legal complexity and risk associated with irrigation efficiency projects due to their capital-intensive nature and legal uncertainty regarding the availability of water savings to be rededicated to instream flow.

4.2.2.2. Legal and economic. Legal and economic barriers are closely intertwined. Irrigation return flows are often the basis for downstream water rights, and water transfers are governed by the legal principle of "no harm" to junior appropriators. Because environmental water transfers, like other water transfers, often change the pattern of return flows, they are subject to legal injury analysis to ensure upstream and downstream diverters are not impaired (Pilz, 2006). This condition has led to administrative reviews that can require a year or longer to complete for permanent transfers, leading some practitioners to perceive a double standard that restricts instream transfers from achieving environmental benefits downstream of the point of historical return flows. In a similar vein, the need to assure irrigation districts that out-of-district transfers will not impair district operations and finances has led to the use of exit fees. Exit fees may be considered an economic barrier tied to group water ownership and infrastructure systems (see the Murray-Darling case below). At the same time they can be thought of as an adaptation that enables collaborative, long-term relationships to be built with large irrigation districts (see further discussion under adaptation below). Exit fees are an example of the need – in an incentive-driven and collaborative process – to ensure potential losers are treated fairly by offsetting or eliminating negative side effects from transactions. Both the direct and transaction costs of ensuring a win–win solution add to the costs of undertaking transactions. As such they pose a financial barrier, but are more appropriately considered as part of the true economic costs of a collaborative, transactional approach.

4.2.2.3. Environmental. A final class of barriers is tied to environmental factors, particularly due to the uncertainty stemming from groundwater–surface water interactions (Stillwell, 2007). The growing urban and peri-urban development for amenity-based communities has led to a proliferation of small-scale domestic wells that cumulatively can diminish surface flows, undermining both instream flows and senior surface water rights. The institutional framework for environmental water transfers that aims to generate net increases in instream fish habitat has been adapted to the context of groundwater–surface water interactions. Groundwater mitigation banks, such as those established in the Deschutes and Walla Walla Basins, prevent against the net loss of instream flows by requiring new water users to offset the impact of their water use on existing users by retiring surface water rights in hydrologically connected parts of the watershed (WDOE and WWT, 2007).

4.2.3. Learning and adaptation

The complexity and uncertainty inherent to ecosystem restoration and water governance more generally reinforce the importance of adaptive learning in market-based instream flow restoration in the Columbia Basin.

4.2.3.1. Economic adaptation — exit fees. As indicated above, a collaborative, incentive-based approach to environmental water allocation requires mechanisms to ensure that transactions minimize or offset negative impacts. The transfer of water out of irrigation districts presents both obstacles and opportunities because districts can control a suite of rights and deliver water along shared conveyances, creating an important jurisdictional and infrastructural overlay on water allocation rules and water transfers. These districts depend on a critical mass of patrons to support the infrastructure, maintenance, operation, and physical viability of the water delivery system. Defection of sufficient numbers of irrigators threatens the financial and operational viability of shared conveyances. In the Deschutes Basin, collaborative negotiations led to the formulation of district exit policies. These policies rely on the notion of an exit fee imposed on transfers out of a district. In some fashion, the fee offsets the lost stream of revenues generated through annual fees collected from irrigators for operating and maintaining irrigation infrastructure. Districts in the Deschutes deposit such payments into an endowment that covers the forgone annual assessment fee to support the district's operations and maintenance costs. This economic barrier to transactions has therefore been addressed by paying the exit fee, as part of a concerted effort to avoid financial harm and to maintain a collaborative relationship with district managers and users.

4.2.3.2. Institutional adaptation. Implementation efforts have included a primary role for government agencies and non-profit organizations. Successful implementation requires establishing

credible environmental flow priorities, navigating complex agency procedures and transfer rules, and engaging willing sellers. An important institutional adaptation entails the development of organizational capacity and institutions (Table 1). In 1993, the Oregon Water Trust formed to capitalize on then-untested statutory authority created by the 1987 Instream Water Rights Act which enabled private entities to purchase or lease water rights for instream flow restoration (Neuman and Chapman, 1999). Programs have since proliferated in surrounding states as Washington and Montana formed water trusts in 1998 and 2002, respectively (King, 2004; Ferguson et al., 2006).

The role of scale has been important in the authorization, design, and implementation of acquisition programs. Transactional activity has been organized and administered by a varying mix of local, state, and federal mandates and agencies and by public and private organizations at multiple scales. Federal acquisition programs are prominent in basins with federally sponsored water storage projects, such as the Yakima and Upper Snake Rivers of Washington and Idaho, respectively (see Malloch, 2005 for the Upper Snake). These programs have achieved large scale temporary acquisitions due to the presence of a high storage-to-natural flow ratio and the ability to institutionalize the reallocation of stored water supplies through irrigation efficiency and leasing efforts. Accordingly, federal programs have generated a substantial proportion of total transactional activity to date (Landry, 1998; Scarborough and Lund, 2007; Brewer et al., 2008); however, more recently, acquisition programs have developed through statewide legislative reform coupled with local institution building and regulatory reform at or near the watershed scale. For example, non-profit or quasi-governmental basin organizations have formed to conduct outreach and to plan and implement environmental water transfers in the Deschutes (OR) and Walla Walla (OR/WA) Basins. Statewide programs with watershed-level priorities are authorized and implemented by both state agencies – ID and WA – and non-profit water trusts in OR, MT, and WA.

4.2.3.3. Monitoring and compliance. The mobile, variable, and, hence, uncertain character of water rights acquisition and transfer for environmental purposes has required institutional capacity to monitor and enforce environmental water transactions to ensure compliance and effectiveness. Three questions are applied in the process of monitoring, compliance, and effectiveness: Do landowners comply with agreements to modify or reduce water use to enhance instream flows for fish habitat or groundwater mitigation benefits?

Table 1
Implementation programs.

	Murray-Darling Basin			Columbia Basin			
Program title (data source)	The Living Murray	Common wealth water recovery — restoring the balance	Riverbank	Columbia Basin water Transactions program (a)	Deschutes River Conservancy (b)	State water trusts	State agency (c)
Location	River Murray system (NSW, Victoria, South Australia)	Murray Darling Basin	NSW section of the Murray-Darling Basin	Columbia Basin	Deschutes River (OR)	Montana Oregon Washington	States have different mixes of acquisition programs, financing mechanisms, and/or market regulation (multiple roles)
Volume restored[a] (m^3 millions)	20[b]	To be determined	27	112 (2007)	53 (2006)	*Varies*	*Varies*
Financing[c] (US $ million, 2007 budget unless noted)	$24.8 (Pilot)	$2.1 billion in U.S. dollars over ten years	$69 (2007−11)	$4.6 (water) $6.5 (total) including cost-share	$3.3 (water/ infrastructure) $4.4 (water and transanction costs)	*Varies*	*Varies*, e.g. $3.5 Washington (2001–3 Biennium)
Transaction							
Irrigation efficiency	Present	Present	Present	Present	Present	Present	Present (except Idaho)
Expression of interest/reverse auction	Present	Present	Present	Present	Present	Present (Oregon Washington)	Present (Oregon Washington)
Market purchase or lease[d]	Absent	Absent	Absent	Present	Present	Present	Present
Organizational form of buyer	Basin non-profit	Federal Agency	Regulatory agency	State agency and Non-profit	Basin Non-profit	Non-profit	Regulatory agency
Environmental water use	Instream/offstream	Instream/offstream	Instream/ offstream	Instream	Instream	Instream	Instream

Data sources (financing and amount):
For *Murray-Darling Basin*, see Garrick et al. (2008). For *Columbia Basin*, see (a) Columbia Basin Water Transactions Program 2007 Annual Report (note: financing includes cost-share); (b) *financing* – Deschutes River Conservancy (DRC) Fiscal Year 2007 Non-Profit Tax Exempt Disclosure Form (IRS Form 990) and *volume* – DRC 2006 Annual Report (based on 120 ft^3/s, or 3.4 m^3/s of restored flow basin-wide extrapolated over a 180-day season of instream use); (c) Financing reflects Washington state legislative appropriation for the Washington Water Acquisition Program over the 2001–3 Biennium, see Adelsman (2003).

[a] Volume. The metric of water volume restored should be interpreted relative to established environmental flow needs, but this information is not consistently available. The metric of water volume restored has different significance in the two countries. Volume in the Murray-Darling refers to annual planned *flow targets*. The Australia water volume data simply reports the goals for environmental water allocation rather than physical outcomes of transactions completed through 2007. In the Columbia Basin, the volumes reported refer to the amount of water that was acquired and managed as an environmental water right during the year noted in parentheses. The aggregate volume of water physically reallocated instream on an annual basis is a function of (a) water acquired through leases and transfers initiated in the given year plus (b) long-term environmental water transactions carried over from previous years.

[b] Target volume of 20 million m^3 is part of a comprehensive recovery effort to acquire 500 million m^3 for delivery to icon sites on the River Murray.

[c] Financing levels refer to annual expenses – either budgeted (Australia) or actual (U.S.) – reported in real dollar terms and rounded up to the nearest hundred thousand. Exchange Rate: $1 AUS = $0.69 US (December 2008). In the case of the Columbia Basin, actual expenses include the water costs and organizational programmatic costs, which are a component of the total transaction costs of implementing environmental water transfers.

[d] The terminology used to define market contract types (purchases and leases) differs between the Columbia and Murray Darling Basin contexts. A market purchase or lease in the Western U.S. entails a negotiated exchange between willing buyers and sellers, and the transaction does not always proceed through a formal water exchange, such as a water bank or reverse auction process. In Australia, market purchases or leases refer to private trades on established water exchanges. Government-brokered environmental water rights acquisitions in the Murray-Darling utilize expressions of interest procedures that remain independent from water exchanges established for private trading; therefore environmental water rights acquisitions in the MDB context do not represent market purchases or leases per se.

Does water acquired for the environment effect intended biological, hydrological or ecological outcomes? Does the public and private investment in water rights acquisition achieve desired ecosystem condition and function while upholding standards of equity, efficiency, and cost-effectiveness? The first answer – water user compliance – remains a threshold determination in designing and implementing environmental water transfers. Monitoring and enforcement is administered by authorized regulators, known as watermasters or stream patrols, who uphold instream water rights by measuring water use and distribution and devising schedules and flow rates to trigger enforcement of instream flows during peak water use. The complexity and uncertainty usually surrounding water rights, such as the lack of adjudication or proof of historic use, make water regulation difficult and complaint-driven, opening a role for supplemental monitoring by the non-profits initially brokering the acquisitions. As of 2007, all non-profits in the Columbia Basin Water Transactions Program have at least a part-time position dedicated to monitor streamflow levels to gauge the compliance of water users who have entered into a contract to suspend or alter water use to restore fish habitat. This adaptation has proven necessary due to the resource constraints faced by regulatory agencies as well as the growing public accountability burden to document the legal and ecological effectiveness of environmental water transfers supported by public dollars.

4.2.3.4. Evaluation. The need for monitoring and adaptive learning extends beyond issues of compliance to encompass a broader need to evaluate the biological, ecological, and implementation effectiveness of water transfer programs for environmental flow allocations. In 2007, the Columbia Basin Water Transactions Program contracted a third party evaluation to assess the program pursuant to the Program's initial mandate from the RPA 151 of the 2000 Biological Opinion for the Federal Columbia River Power System (NMFS, 2000). The independent evaluation by Hardner and Gullison, LLC (2007) underscored the need to integrate water transfers with larger restoration efforts to attain targeted ecological outcomes for fish recovery. The findings of the evaluation identified limiting factors through interviews with leading agency and non-profit implementing bodies, yielding three major factors impeding water transactions, namely: coordination of donor support for financing, existence of willing sellers, and transaction costs, although individual organizations encountered other barriers tied to science, policy, and economic circumstances. This evaluation has spurred adaptation by establishing flow restoration targets and developing integrated strategies to maximize salmon habitat recovery.

5. Murray-Darling Basin

The policies that underpin environmental water transactions in the southern Murray-Darling Basin have their origin in regulations that were designed to enable willing buyers and sellers to transfer allocation and entitlements between one another. Environmental water transaction programs use these already established markets to purchase water rights. Similar to the Columbia Basin, a number of aspects of policy evolution can be followed, from setting the cap and enabling water transactions to the establishment of the environment as a legitimate user.

5.1. Enabling conditions

5.1.1. Limits (the cap)

Rules governing water access by irrigators in the Murray-Darling Basin (MDB) have been the domain of individual states because the Australian Constitution does not include “water resources” as one of the subjects about which the Commonwealth may legislate (Dyson, 2008). As a result, the distribution of water rights has been administered by state governments. A major issue at the time of Federation in Australia in 1901 was the way in which water should be shared at a bulk level between the southern MDB states of New South Wales (NSW), Victoria and South Australia. This was not resolved until 1914 when the states agreed to the River Murray Waters Agreement, which stipulated the rules for sharing the waters of the River Murray system. This was followed by the establishment of the River Murray Commission in 1917 to implement the Agreement. The Basin then entered a period of increasing diversions, with much of the Agreement dealing with how to increase storage and regulate the River Murray's water resources.

The first signs that an increase in water extraction may need to be curbed was in South Australia when in 1969 a moratorium was placed on the issue of new entitlements (Bjornlund and McKay, 1998). This moratorium was followed by a compulsory reduction in the total volume of entitlements in South Australia by nearly 10% in 1973.

Community concern about the deterioration of the Basin's river systems saw the Murray-Darling Basin Ministerial Council direct the preparation of an *Audit on water use in the Murray-Darling Basin*, which was released in 1995 (Murray-Darling Basin Ministerial Council, 1995). This contained modeling that suggested further increases in water diversions from the Basin would jeopardize the security of water supply for existing irrigators and may further exacerbate environmental problems. In response to the Audit a limit was set on the volume of water that could be diverted from the river system for consumptive use. The cap began in 1997, being set at the *volume of water that would have been diverted under 1993/94 levels of development* (MDBMC, 1998). The MDB Cap has placed a limit on diversions since that time; however, continued overallocation exacerbated by prolonged drought has seen further deterioration of the environmental condition of the rivers and wetlands of the Murray-Darling Basin. The Federal *Water Act 2007* will see a new Basin Plan developed that will reassess restrictions on water extraction, across both ground and surface water.

5.1.2. Water transfers

The start of limits being placed on diversions during the 1970s in South Australia meant that the only way for irrigation to expand was through trade in water entitlements, which was facilitated with the release of an enabling policy in 1983 (Tuckwell, 1984). The key feature of this policy was that it enabled water to be transferred separate from land. NSW, Victoria and South Australia had all adopted legislation or policies enabling the trade of annual allocations by 1987 and for entitlements by 1991 (Murray-Darling Basin Ministerial Council, 1995). Importantly, these reforms were driven by the desire of irrigators to expand the area under production in the face of limits on the aggregate use of the resource, rather than to support environmental purposes (Bjornlund and O'Callaghan, 2003).

A multi-jurisdictional approach emerged with the COAG Water Reform Framework in 1994 and paved the way for the MDB Ministerial Council to launch an interstate trade pilot project in 1998, with the rules being laid out in a schedule to the Murray-Darling Basin Agreement. The scope of the trial expanded in November 2003 driven by the firm direction of COAG's June 2004 National Water Initiative (Cummins and Watson, 2007). Interstate trading was formally adopted by the Ministerial Council in May 2006, enabling water entitlement trade across the entire southern connected Murray-Darling Basin.

5.1.3. Environment as legitimate use

The River Murray environment has been the beneficiary of standard operating rules, such as the requirement for minimum flow releases from Hume and Dartmouth Dams, which are the largest storages on the River Murray. However, while the minimum daily release volumes did provide some instream environmental benefits, they were not entitlements that could be called upon to deliver water

for specific environmental purpose in the same way irrigation water could be requested and delivered. In 1994, COAG's Water Reform Framework paved the way for such entitlements by requiring the need to formally "determine allocations for the environment as a legitimate user of water". Environmental water is now provided through statutory plans and accounted for under a variety of entitlements, many of which are stated based mostly state based (e.g. MDBC, 2006).

To summarize, the result of water reforms that arguably started in the 1960s and 70s, has been the establishment of a basin-wide cap and trade system, in which the environment can participate as a legitimate user and market participant. The resultant system does not follow a consistent path to create a regulated market for goods and services. Instead, the environment has become recognized as a legitimate participant in the existing market place.

5.2. Implementation drivers, barriers and adaptation

5.2.1. Drivers

5.2.1.1. Demand drivers. A major driver of programs to recover water for allocation to the environment has been the mounting evidence of the declining condition of river and floodplain health. Initially policy reforms such as the 1995 Audit of Water Use in the MDB (Murray-Darling Basin Ministerial Council, 1995) identified separate factors such as declining water quality – demonstrated by increasing salinity and algal blooms – and declining native fish populations as evidence of environmental degradation. Following COAG's 1994 directive to ensure that work to define environmental water requirements was underpinned by scientific evidence, there were increased efforts to synthesize available data and generate an ecosystem view on health. This led to conclusions, such as that of the Jones et al., 2002, that the condition of the river environment had declined so much that it could be considered *unhealthy*.

The decline in condition has been attributed to a number of factors, including introduction of pest plant and animal species (e.g. common carp), removal of large woody debris from river channels, floodplain grazing, and barriers to fish movement such as locks and weirs (Thoms et al., 2000). However, the dominant factor has been changes to the flow regime, due to river regulation and diversions that have led to reductions in the magnitude and frequency of floods, changes to the seasonality and the rate of rise and fall.

The development of the policy framework to establish the water market occurred alongside reforms to address the decline in the health of the river system. The COAG 1994 Framework called for the States to formally determine allocations or entitlements to water for the environment based on the best scientific information available. This directive was followed by numerous studies and reports on the flow requirements of the southern MDB rivers (Thoms et al., 2000; Jensen et al., 2000) and the benefits of returning varying volumes of water to the river environment (SRP, 2003). This work ultimately underpinned a number of government decisions to invest in programs to secure dedicated environmental entitlements. For example, the *Intergovernmental Agreement on Addressing Water Overallocation and Achieving Environmental Objectives in the Murray-Darling Basin* that was agreed to by COAG on 25 June 2004 gave effect to the August 2003 decision of southern MDB jurisdictions to the Living Murray initiatives First Step decision. Other programs that use transactional approaches are also supported by enabling policies or plans (e.g. operation of water trusts; DWLBC, 2005). The most recent and significant water recovery program is under the Australian Government's *Restoring the Balance in the Murray-Darling Basin* program, which forms part of the Australian Government's $12.9 billion national plan on water. Under this plan, the government has committed $3.1 billion to purchase water in the Murray-Darling Basin over 10 years.

Drought has arisen as another driver for environmental water recovery programs in recent years, perhaps more powerful than any of the preceding scientific analysis. The catchments of the southern Murray-Darling Basin have been suffering the effects of below average rainfall and, therefore, river flows for much of the past 6 years. With the exception of 2005–06 there have been none of the above channel flows for much of the length the River Murray that are essential to maintain the health of a floodplain river system like the Murray. This comes on the back of the already reduced flooding magnitude and frequency due to diversions. The results have been ecologically devastating and include no flow through the mouth of the River Murray since 2005–06 requiring the use of sand pumping (dredging) to maintain an open mouth and the potential for some areas of the Lower Lakes and Coorong Ramsar-listed site to develop acidified soils as falling water levels expose traditionally permanently inundated sediments. The community concern raised over the decline in environmental condition since the Brisbane workshop has resulted in greater political pressure to address overallocation issues.

5.2.1.2. Institutional drivers. The case studies presented at the Brisbane workshop gave examples of two large scale multi-jurisdictional, government programs in Australia; a smaller single jurisdiction program and an independent, non-government not-for-profit program. That being said, the approach to water recovery for environmental flows in Australia is clearly in favor of government operated programs.

The large transactional approaches in Australia have favored voluntary expression of interest or tender programs (known as a reverse auction in the U.S. context). Two such efforts are The Living Murray (TLM) and Riverbank. These projects involved receipt of expressions of interest from willing sellers over a set period of time. Both managers reported that the programs had been oversubscribed. The success of such approaches has continued with purchasing programs implemented since the Brisbane workshop with a combined Riverbank — TLM expressions of interest program and the first round of the Commonwealth's expression of interest programs meeting their goals.

A major advantage of purchasing entitlements in an established market is that pricing information is more easily available. For example, a number of water exchanges exist in the southern MDB that provide pricing data on annual allocations or permanent entitlements, which when combined with data from state registries can provide a pricing guide.

5.2.2. Barriers

5.2.2.1. Regulatory. Water reform in Australia has meant that environmental managers are considered legitimate players in the market and are subject to the same rules as other entitlement holders. The major regulatory barriers are, therefore, the same as apply to all market participants, although there are some that are of more direct interest to environmental water purchasing programs. For example, the *Intergovernmental Agreement On A National Water Initiative* allows irrigation districts to cap permanent transfers at 4% annually. This restriction on trade has meant that some government agencies have entered into contracts for purchase of water for environmental programs only to find that the cap has been breached requiring them to re-submit an application to trade at the start of the following season, with no guarantee that the transfer will be permitted that year either. Caps also exist in other forms, such as the Victorian Government's 10% investor cap, which prevents water entitlement holders that do not own property within an irrigation area from holding more than 10% of all the shares allocated to that area.

Another oft cited barrier to trade is that of exit or termination fees. These fees apply in irrigation districts where a bulk entitlement is held by an irrigation company, and irrigators are entitled to a share of the entitlement. If an irrigator wishes to sell their water to a buyer outside

the district, which is the case for most environmental purchasing entities, they may be required to pay an exit or termination fee, which may be a fixed payment per megaliter traded out (Productivity Commission, 2006). The justification for the fee is that it provides funds for the ongoing maintenance of infrastructure within the district. However, where these fees are high and if they represent a substantial portion of the total value of the entitlement they create a disincentive for entitlement holders to sell. The Productivity Commission (2006) concluded that exit fees can reduce the economic welfare of buyers and sellers of entitlements in both trading regions and are a barrier to trade. New termination fee rules went into effect under the Federal *Water Act 2007* in August 2009, resulting in more stringent conditions under which termination fees can be levied.

5.2.2.2. Social and cultural. The negative response of some sectors of regional and rural communities to water recovery programs in the southern MDB initially appeared to be one of the greatest barriers to progressing to an implementation phase. In the case of the Living Murray, opposition grew during the initial scoping of the program. Concern generally centered on the view that large scale reductions in water entitlements may lead to decline in the viability of some communities and ultimately to their demise. Despite such concerns, governments have made clear commitments to further reduce diversions.

The social response to market purchase can be complex. On one hand, water user groups may be concerned about the loss of water from their district and, therefore, be in support of caps on trading out of irrigation areas, yet those who are not able to sell water out of an area are unable to capitalize on the sale of water entitlements that may be their most valuable asset.

5.2.2.3. Environment. While drought has been a driver of change by means of raising community concern about the resulting environmental degradation, for a program like the Healthy Rivers Australia (HRA)[1], it has also been a major barrier. HRA started with the intention of receiving donations of water from entitlement holders. This idea was conceived when allocations on entitlements were high, the price of allocations was lower, and any unused water at the end of the season had to be forfeited. Drought changed all of this: low allocations meant that irrigators had little unused water at the end of the season, the price of water increased because of its scarcity making it more attractive to sell on the market, and, finally, carry-over provisions were introduced to enable irrigators that had unused water at the end of the season to retain it for use in the following season. Combined, these factors meant that water donations were very small. The result being that the focus of HRA and other NGOs with a similar business model, are looking to financial donations that can be used to purchase water on the market.

5.2.3. Learning and adaptation

5.2.3.1. Institutional adaptation. The success of government entities purchasing water in the market has meant that there has been little change to the supporting institutional arrangements. However, HRA faced a different fate in 2006–07 and 2007–08 when in the face of rising water prices, along with drought, few entitlement holders were willing to donate water, especially given there were no financial incentives such as tax concessions on donated water. The focus of this NGO is now firmly on seeking financial donations to purchase water from the market, placing it in direct competition with government buy back schemes. There are now a number of NGOs in Australia that have expressed an interest in using markets to obtain water for community projects, approaching a similar role of community engagement and project development pursued by non-profit water trusts and river conservancies in the Western U.S.A.

5.2.3.2. Monitoring and compliance. Monitoring and enforcement of the water market in the southern MDB can be viewed from a number of perspectives. At a broad scale, the implementation of the Cap is audited each year by the Independent Audit Group, which reports annually to the MDB Ministerial Council (e.g. Flett et al., 2008). States are required to address any over use against the cap. At an entitlement holder scale, the relevant state government authorities or irrigation companies monitor water use and have the capacity to issue fines for overuse.

With respect to monitoring and compliance for water obtained through transactional approaches, the purchase of entitlements means that in most instances the water can be ordered from regulated storage and thus releases can be accounted for as they would be for irrigation. Monitoring water use will be more complex though. While small-scale projects involving pumping can track water delivery accurately, consumption of water on large floodplain wetland complexes such as the Barmah-Millewa Forest or Chowilla Floodplain will prove more difficult. However, these challenges are not unique to water recovered via markets and will need to be tackled regardless of the recovery mechanism.

5.2.3.3. Evaluation. Evaluation can be viewed from two different perspectives: Does the program secure the desired water rights, and does the program deliver the environmental outcomes sought? Efforts to date have certainly met water recovery or expenditure targets through the use of tender programs. However, the volumes recovered have been small compared with the volume of entitlements. For example, the TLM pilot purchase program purchased 20 GL, which represent a small percentage of all entitlements in the Southern MDB.[2]

The test for the current approach of seeking expressions of interest from willing sellers will be the ability of the market to supply the larger volumes of water that will be sought through programs such as the Australian Government's purchasing programs.

Another challenge for governments buying entitlements is that allocations are so low under current low water resource availability conditions that the available water on purchased entitlements is small in volume. For example, the 50 GL of entitlements purchased at the end of the 2007–08 water season, would have had less than 5 GL of water allocated to it based on announced allocations by relevant state governments. This had led to criticisms that the environmental water recovery programs are buying "paper" water only.

6. Conclusions

Tietenberg (2002: 224) concluded his survey of market approaches to the commons with a comment that echoes the experience with market approaches to environmental water allocation, namely that "the evidence seems to suggest that tradable permits are not a panacea, but they do have their niche." The evidence presented here from well-developed cases demonstrates that using water markets and a transactional approach to water rights reallocation can be an important strategy to achieve implementation of environmental flows. This evidence also underscores that markets are mere extensions of institutional arrangements and governance regimes. The conceptual framework and case studies reinforce this paper's core argument, namely that policy reforms are necessary but insufficient to catalyze market-based transfers to restore environmental flows, requiring attention to a set of drivers, barriers, and adaptations that affect implementation effectiveness.

[1] Healthy Rivers Australia was formerly known as Waterfind Environment Fund.

[2] As the manuscript went to press, the Australian Government announced that it had secured 545 GL of a mixture of low and high reliability water entitlements from across the Murray-Darling Basin (DEWHA 2009).

6.1. A Framework for employing water markets to provide freshwater ecosystem services

The cases demonstrate a common set of three enabling conditions: policy and regulatory reforms (following Tietenberg, 2002 and Aylward, 2008a):

1. establish rights to and limits on freshwater extraction and allocation
2. authorize the environment as a legitimate (beneficial) use
3. authorize transfer mechanisms to reallocate water for the environment.

These enabling conditions represent fundamental steps necessary to motivate a cap-and-trade market applied to the case of environmental flows. This paper and the Columbia and Murray-Darling cases demonstrate this application and show the different ways such reforms evolve under different jurisdictions. Both cases involve water rights systems that have inherent priority systems and these priorities underpin traditional water right trades as well as environmental water trades. As such these reforms are necessary but not sufficient to deliver environmental flows. For as long as other uses of water have a positive economic value water will not move to environmental uses without effective environmental demand in the market.

The cases reviewed here suggest that there is a further set of drivers, barriers and adaptations that determine participation and outcomes in environmental water transactions. The cases share the following set of drivers:

- effective financing mechanisms that overcome the public goods problem associated with environmental flows and convert demand drivers into financial flows for transactions
- governance and jurisdictional issues that determine the size of the market and the level of coordination required to ensure local transactions projects generate cumulative benefits at appropriate ecological scales.
- institutional capacity to plan, implement and coordinate transactions for environmental flows
- administrative capacity and procedures to monitor and enforce water allocations and to minimize or offset negative social and environmental impacts.

The cases demonstrate that the three enabling policy and regulatory conditions for markets and environmental water transfers are necessary but not sufficient to elicit large-scale participation and outcomes. However, differences in institutional settings underpin distinctive paths to implementation of market-oriented environmental water allocations. A comparison and contrast of the cases on these dimensions follows below.

6.2. Implementation lessons from the case studies

6.2.1. Financial mechanisms and demand drivers

Demand for environmental water allocation is spurred by intensified scarcity combined with growing concern for degraded ecological conditions along instream and floodplain habitats. Crisis conditions due to drought, endangered species, or rapid urbanization catalyze several enabling reforms and capacity for implementation. Scarcity and prolonged drought in the Murray-Darling and salmon habitat degradation in the Columbia Basin provided the proximate force driving demand for reallocation. In both cases, the vast majority of financing has come from the public purse. In the Murray-Darling, federal government funds have been authorized to resolve the water crisis through acquisition and irrigation efficiency projects targeted by basin plans to support farmers and provide environmental flows. In the Columbia, funding has largely been generated under mitigation commitments forced through application of the Endangered Species Act and watershed-level groundwater cap-and-trade systems.

6.2.2. Institutions and governance

Implementation programs and outcomes are governed by different institutional arrangements in the Columbia and the Murray-Darling. Two characteristics of the governance regime are noteworthy, namely the role of the non-profit sector and the level of federal involvement in policy reform and implementation. First, the role played by non-profit organizations in policy reform and implementation is more prominent in the Columbia Basin and Western U.S.A. than in the Murray-Darling where government-centered programs have developed through state, basin-wide, and national public policy reforms. Still, it is too early to conclude that environmental flow objectives in the Murray-Darling will be accomplished solely by central government acquiring water through water brokerages. To date, restoration efforts in the Murray-Darling have focused on sites of international and national importance, but this dynamic is changing rapidly. As the feasibility of acquiring environmental flows has been demonstrated, local non-profit organizations aimed at meeting local environmental water needs have emerged (Nias and D'Santos, 2009).The second distinction lies in the involvement of the federal government in the design and implementation of market transactions for environmental restoration. Although an important federal and interstate nexus exists in the Columbia River, regional integration is limited in water allocation matters. Different legal and administrative systems at the state level make cross-border transactions unwieldy and cooperation across state borders between non-profit organizations has been limited. The Murray-Darling has been the focus of major comprehensive interstate coordination, national reform, and infrastructure, leading to larger scale government investments and more punctuated policy reforms that may enable step changes in the distribution of water across human and environmental needs. Thus, governance arrangements have enabled an extremely large water market in the Murray-Darling. To some extent the differing physical contexts and environmental objectives – as discussed further below – have led, in the Columbia, to localized efforts by non-profits versus, in the Murray-Darling, an integrated market in which the federal government is a major environmental buyer.

6.2.3. Barriers and adaptation

Barriers stem from legal, cultural, economic, and environmental sources as part of political economy of water transactions and associated norms of equity and fairness aimed at preventing or offsetting unintended negative consequences to local communities and user groups. Both cases have confronted community concern over the transfer of water from traditional consumptive uses to instream uses or offstream environmental assets. Interestingly, these barriers – and the adaptations sought to overcome them – vary between the cases. For example, while exit fees are viewed as a positive adaptation that is economically justified in the Columbia, they are viewed as a barrier to trade in the Murray-Darling. In the case of harm to third party water users, this has been a major issue and barrier to transactions in the Columbia — whereas in the Murray-Darling it is generally not an issue because downstream water rights depend less upon the return flows from upstream diversions than in the Western U.S. As a consequence, trades of temporary water in the Murray-Darling take as few two days to conclude but from thirty days to a year in the Columbia.

6.2.4. Context and environmental objectives

The two cases exhibit close similarity in the set of reforms undertaken, whereas the drivers, barriers and adaptations vary substantially. This pattern of reform and implementation suggests that a similar set of basic enabling conditions applies across different contexts and environmental objectives. The fish habitat recovery and groundwater mitigation focus of environmental water transfers in the Columbia Basin has directed implementation efforts to small tributaries or local zones of hydrological impact where a single agreement or set of

agreements with water users or irrigation district patrons can restore fish habitat along flow-limited tributary reaches. Although larger scale restoration efforts in the Columbia have spawned watershed institutions (e.g. Deschutes and Walla Walla Rivers) or reallocation of water stored and regulated by a dam, the historic emphasis on "unregulated" natural flows is distinct from the physical and infrastructural setting in Murray-Darling. The offstream floodplain wetlands and other environmental assets targeted by environmental water transfers in the Murray-Darling depend on storage infrastructure to regulate deliveries of acquired water to coincide with existing flow events.

6.3. Delivering outcomes? Evaluating effectiveness

Applying this conceptual framework to an in-depth comparative analysis indicates that market-based approaches *can* deliver water rights for environmental purposes if the political will and driving economic and environmental forces create momentum for required policy reforms and implementation capacity. Restoration ecologists have demonstrated that enhancing steamflow can trigger biological improvements for freshwater species whose habitat is vulnerable to chronic low flows or seasonal dewatering (see e.g. Covington and Hubert, 2003), while others have documented the wider economic benefits of preserving or restoring a flow regime to optimize provision of freshwater ecosystem services (see Poff et al., 2009; Postel and Richter, 2003). The ability of market approaches to generate net increases in streamflows – even in marginal terms – is particularly salient due the perceived failures of previous policy initiatives which prescribed protections for environmental flows by central regulation or decentralized collaborative decision-making but did not deliver "wet" water until market mechanisms emerged (Neuman, 2004; Neuman et al., 2006). However, the scale and magnitude of demand for environmental water allocation dwarfs the level of allocations secured through markets to date, which suggests the need for more rigorous, interdisciplinary standards for assessing policy effectiveness. In the context of market-oriented approaches to restore rivers and enhance provision of freshwater ecosystem services, initial implementation efforts are only in the earliest stages, and a comprehensive evaluation and determination of policy effectiveness is therefore premature. However, this section of the article elaborates key aspects of a comparative policy evaluation framework that can measure and assess the relative performance and progress of alternative institutional arraignments toward larger scale ecological outcomes.

The multi-dimensional question of policy effectiveness requires long-term attention and longitudinal analysis, as ecological indicators may respond slowly to changing water availability. In this regard, although it is premature to assess the efficacy of market transactions for meeting environmental water needs until more implementation experience accrues, the need for monitoring and evaluation is widely recognized in the development of reallocation targets, benchmarks, and monitoring standards and protocols (CBWTP, 2008; UDWC, 2009). At this stage of policy design and implementation, keen emphasis has been placed on devising the fundamental metrics for assessing and tracking effectiveness in legal, ecological, and political economic terms, such as compliance monitoring standards, ecological indicators, the number and type of transactions, water volume, cost of water, and transaction costs, among others (Brewer et al., 2008; Aylward 2008b).

Three classes of metrics have emerged to define standards and criteria for evaluating policy design and implementation effectiveness.

1. Legal (Transactions) Compliance: Do market transactions result in physical increases in stream flow at the times and places required for environmental benefits? Do sellers comply with the terms of the contract to modify water use in accordance with the environmental objectives addressed through the transaction?
2. Ecological Effectiveness: Have increases in streamflow yielded ecological outcomes at a scale sufficient to stem or reverse declining conditions in freshwater ecosystems? Have transactions been integrated with conservation mechanisms targeting other limiting factors to enable synergistic effects and step changes in ecological conditions?
3. Political Economy of Water Transactions: How do market-oriented policy approaches to reallocate water for environmental purposes compare to and interact with other policy alternatives based on political economic criteria, including equity, accountability, and efficiency?

These questions are now beginning to receive attention as implementation experience and transactional activity grow (Malloch, 2005; Hardner and Gullison, 2007). For example, in the Columbia, participating non-profits and state agencies are actively engaged in demonstrating legal (transactions) compliance, including the development of new criteria, standards, and capacity for compliance monitoring. Since 2000, new staff positions, monitoring technology and infrastructure have developed capacity to verify compliance in terms of fallowed land, irrigation diversions and streamflow levels downstream from the historic point of diversion (e.g. see Case, 2008).

Ecological effectiveness criteria guide the goals and design of water rights acquisition programs and strategies (Adelsman, 2003) in an effort to maximize the ecological return of public and private investments in environmental water transactions. Therefore, after confirming compliance, implementing organizations conduct long-range monitoring to determine whether intended ecological effects are realized, requiring metrics of biological changes (species level), habitat quality, and overall ecological health that capture the streamflow–ecological relationships affected by environmental water transactions (Hardner and Gullison, 2007; Poff et al., 2009) . Ecological responses to environmental water transactions are mediated by several factors outside the scope of the transaction, raising the importance of coordination with other conservation strategies and resource management activities. Thus, as implementation efforts have expanded, organizations undertaking transactions in the Columbia coordinate with state and federal fish and wildlife staff and academic researchers to undertake long-term habitat and biological monitoring programs (see e.g. UDWC, 2009).

The type of environmental water needs in the Columbia Basin – and the accumulated experience with transactions over the past decade and a half – makes it possible to render preliminary assessments about the ability of to establish a causal link between the water acquired through market mechanisms and observable changes in ecological conditions. The effect of incremental changes is observable in the Columbia because transactions target localized environmental water needs in tributaries where a relatively small increment of water over a short period (late summer) can restore habitat that was traditionally de-watered. In these localized contexts, transactions have been used to restore habitat connectivity in tributaries in the Columbia Basin, such as the Lemhi River of the Upper Salmon Basin where five-years of habitat modeling and monitoring have determined that water transactions have improved habitat availability for threatened Chinook Salmon and Bull Trout fisheries (Case, 2008). In other cases, complementary institution-building processes have enabled larger-scale ecological outcomes through market transactions. For example, the Deschutes River Conservancy of Central Oregon has restored sufficient environmental flows through market transactions to reach half of its environmental flow target (3.64 of 7 m^3) after engaging in a decade-long process of partnership building and institutional reform to embed market transactions in water banks and other institutionalized partnerships among multiple urban and environmental buyers, irrigation districts and small-scale farming sellers, and non-profit and regulatory agencies at the local, state, federal, and tribal levels (Hubert et al., 2009).

In the Murray-Darling the recent onset of efforts to acquire water for environmental flows, combined with the devastating drought, mean that as of yet little can be said about transactions compliance or

ecological effectiveness. Nevertheless, there have been small volumes of water delivered to high priority wetlands as a result of entitlements and allocations purchased through the market or resulting from water conserved by irrigation efficiency projects (see Nias and D'Santos, 2009). For example, Healthy Rivers Australia delivered 15 ML to three wetlands in the South Australian Murray between 2008 and 2009 with allocation purchased on the market and from water donations. The Australian Government produced 8.4 GL of allocation to a number Ramsar-listed wetlands in May and June 2009 from entitlements purchased under the Water for the Future plan (DEWHA, 2009).

The need for a thorough consideration of the political economy of water transactions arises due to the distributional implications of reallocation: environmental benefits are widely shared and costs are concentrated on historic resource users. In its emphasis on equity and broad criteria for defining public policy effectiveness, such as accountability and allocative efficiency, a political economy perspective helps explain the appeal of incentive-based water transactions relative to approaches involving negative- or zero-sum outcomes of reallocation through coercion; in this vein, it has been noted that prior policy and institutional reforms relying on centralized regulation or decentralized collaboration *alone* have proven insufficient to deliver reliable water rights for environmental purposes at the necessary scale (Gillilan and Brown, 1997; Neuman, 2004; Productivity Commission, 2006).

A research program of comparative institutional analysis and evaluation is needed as policy innovation and implementation spread to new contexts or reach higher levels of transactional activity, especially as alternative policy approaches, such as collaboration or centralized administrative allocation mechanisms, expand alongside and interact with market-based approaches. Thus, future research should extend this comparative framework to examine the diverse institutional mechanisms used to reallocate water rights to achieve environmental sustainability outcomes. In a 2009 follow up to the Brisbane Workshop, the Nature Conservancy, the World Wildlife Fund and the International Union for the Conservation of Nature initiated just such a discussion (Garrick et al., 2009). While no consensus approach or blueprint emerged, practitioners and applied researchers in the field of environmental water allocation underscored the importance of diverse, hybrid approaches that integrate market mechanisms, collaboration, and regulatory reform at multiple scales. The legal, ecological and political economic considerations for evaluating effectiveness outlined here can underpin a framework for assessing the enabling conditions and performance of such policy experiments.

6.4. Implications and future directions

The early adoption and implementation progress with environmental water transfers in the Columbia and Murray-Darling Basin have prompted the question whether these two cases offer models of reform applicable in other physical and political economic contexts, such as less developed economies where freshwater access and use is dictated by informal communal water rights systems and allocation rules. An important question emerging is whether and how these enabling conditions would work in communal water rights systems where there is no inherent priority and water is shared in the face of short supply. Also, the Columbia and Murray-Darling are cases emerging largely from the acquisition of water from irrigators for environmental purposes. The applicability and utility of a transactional approach to environmental flows from hydropower and flood control facilities is an area of further investigation. In the Columbia context, federal control over the hydropower system has resulted in the internalization of such transactions within Bonneville Power Administration itself. While BPA provides mitigation funding to external parties on the order of $170 million as part of its endangered species obligations, it also engages in flow releases each year that may be of a similar order of magnitude in value. In this case, however, they are simply revenues foregone rather than the subject of an environmental water transaction. Similarly, relicensing of private hydropower facilities in the United States generally results in changes in operations or decommissioning that directly lead to environmental flows.

The Brisbane workshop suggests that for countries facing the erosion of freshwater ecosystem services, transactional approaches may provide water to allocate for meeting environmental objectives. However, a different set of barriers may arise in other river basins and countries that prevent the basic policy setting from developing in the first place. For example, there is great political will and collective action required to establish a cap on resource use in the face of mounting opposition from users of the resource, as is currently being demonstrated with debates regarding carbon cap-and-trade systems. In this regard, it should be noted that the policy settings in both countries that were the subject of the case studies evolved over decadal time frames. Further, the basic institutional, technological and human capital required to manage water effectively enough to implement the policy reforms suggested here will be lacking in many countries. However, if the long run intent is sound water resource management – which may eventually include a commitment to reallocation of water to environmental flows – then it can be argued that building the capacity to implement these reforms will be necessary in any event.

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References

Adelsman, H., 2003. Washington Water Acquisition Program: Finding Water to Restore Streams. Publication No. 03-11-005. Washington Department of Ecology.
Anderson, T.L., Johnson, R.N., 1986. The problem of instream flows. Economic Inquiry 24, 535–554.
Anderson, T., Leal, D., 2001. Free Market Environmentalism. Palgrave Macmillan.
Australia Department of Environment, Water, Heritage and the Arts (DEWHA), 2009. Progress of 2008-09 Restoring the Balance in the Murray-Darling Basin Water Purchasing. Available at: http://www.environment.gov.au/water/policy-programs/entitlement-purchasing/2008-09.html.
Aylward, B., 2007. Water transactions for instream flow training. Ecosystem Economics, LLC, Bend, OR.
Aylward, B., 2008a. Water markets: a mechanism for mainstreaming ecosystem services into water management? Briefing paper, water and nature initiative. IUCN.
Aylward, B., 2008b. Restoring water conservation savings to oregon's rivers: a review of Oregon's conserved water statute. A report to the National Fish and Wildlife Foundation. Ecosystem Economics, Bend, OR.
Aylward, B., Bandyopadhyay, J., Belausteguigotia, J., Borkey, P., Cassar, A., Meadors, L., Saade, L., Siebentritt, M., Stein, R., Tognetti, S., Tortajada, C., Allan, T., Bauer, C., Bruch, C., Guimaraes-Pereira, A., Kendall, M., Kiersch, B., Landry, C., Mestre Rodriguez, E., Meinzen-Dick, R., Moellendorf, S., Pagiola, S., Porras, I., Ratner, B., Shea, A., Swallow, B., Thomich, T., Voutchkov, N., 2005. Freshwater ecosystem services: policy responses. Millennium Ecosystem Assessment: Human and Ecological Well-Being. Island Press.
Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P. (Eds.), 2008. Climate Change and Water: Technical Assessment Report #4. Geneva: Intergovernmental Panel on Climate Change.
Bauer, C.J., 2004. Siren Song: Chilean Water Law as a Model for International Reform. RFF Press, Washington, D.C.
Bjornlund, H., McKay, J., 1998. Overcoming the introspective legacy of tradeable water entitlement policies in south eastern Australia. In: Just, R., Netanyahu, S. (Eds.), Conflict and Cooperation on Transboundary Water Resources, pp. 315–332.
Bjornlund, H., O'Callaghan, B., 2003. Valuation and lending implications of the separation of land and water rights. Proceedings from the 9th Annual Conference of the Pacific Rim Real Estate Society, Brisbane 19–22 January.
Boyd, J., 2003. Hip deep: a survey of state instream flow law from the Rocky Mountains to the Pacific Ocean. Natural Resources Law Journal 43 (4).
Brewer, J., Kerr, A., Glennon, R., Libecap, G., 2008. Water markets in the west: prices, trading, and contractual forms. Economic Inquiry 46 (2), 91–112.

Brisbane Declaration, 2007. International Conference on Environmental Flows and 10th annual Riversymposium. Australia, Brisbane. Available at: http://www.nature.org/initiatives/freshwater/files/brisbane_declaration_with_organizations_final.pdf.
Case, M., 2008. Water Transactions Program Monitoring and Evaluation Report 2007–2008. Idaho Water Resources Board. Available at: http://www.idwr.idaho.gov/waterboard/WaterPlanning/Water%20Transaction%20Program/PDFs/MEReport2007_2008.pdf.
Charney, S., 2005. Decades Down the Road: An Analysis of Instream Flow Programs in Colorado and the Western United States. Colorado Water Conservation Board.
Colby, B.G., 1990a. Enhancing instream flow benefits in an era of water marketing. Water Resources Research 26, 1113.
Colby, B.G., 1990b. Transactions costs and efficiency in western water allocation. American Journal of Agricultural Economics 72, 1184–1192.
Columbia Basin Water Transactions Program (CBWTP), 2004. 2003 Annual Report. Available at: http://cbwtp.org/jsp/cbwtp/library/documents/cbwtp-fy03-annual-report.pdf.
Columbia Basin Water Transactions Program (CBWTP), 2008. 2007 Annual Report. Available at: http://cbwtp.org/jsp/cbwtp/library/documents/cbwtp-fy07-annual-report.pdf.
Covington, J.S., Hubert, W., 2003. Trout population responses to restoration of stream flows. Environmental Management 31 (1), 135–146.
Cummins, T., Watson, A., 2007. An Evaluation of the Interstate Water Trade Pilot Project.
Daily, G.C., 1996. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press.
Department of Environment, Water, and Heritage Australia (DEWHA), 2009. Water for the Future. Available at: http://www.environment.gov/publications/action/pubs/water-future.pdf.
Department of Water, Land and Biodiversity Conservation (DWLBC), 2005. Environmental Flows for the River Murray, South Australia's framework for collective action to restore river health, pp. 2005–2010.
Doremus, H., Tarlock, A.D., 2008. Water War in the Klamath Basin: Macho Law, Combat Biology, and Dirty Politics. Island Press.
Dyson, M., 2008. Australian water laws — managing diminishing water supplies in the Murray-Darling Basin. Presented to *First International Legal Colloquium on Regulation and Integral Management of Water*, Cancun, Mexico. October 2008.
Dyson, M., Bergkamp, G., Scanlon, J., 2003. Flow: The Essentials of Environmental Flow. IUCN.
Ferguson, J., Chillcott-Hall, B., Randall, B., 2006. Private water leasing: working within the prior appropriation system to restore streamflows. Public Land and Resources Law Review Journal 27.
Flett, D., Baxter, P., Hillman, T., 2008. Review of cap implementation 2006/07. Report of the Independent Audit Group.
Garrick, D., Aylward, B., Siebentritt, M., Purkey, A., 2008. Environmental Water Transactions: Lessons Learned and Future Prospects. September 2, 2007. National Fish and Wildlife Foundation, Washington, D.C.
Garrick, D., Wigington, R., Aylward, B., Hubert, G., 2009. The Nuts and Bolts of Flow Reallocation. February 22, 2009. The Nature Conservancy, Boulder, CO.
Gillilan, D.M., Brown, T., 1997. Instream flow protection. Island Press, Washington, D.C.
Government Accountability Office (GAO), 2002. Columbia River Basin Salmon and Steelhead: Federal Agencies' Recovery Responsibilities, Expenditures and Actions. Government Accountability Office, Washington, D.C. GAO-02-612.
Hanemann, M. 2006. The Economic Conception of Water. In Water Crisis: Myth or Reality? ed. P.P. Rogers, M.R. Llamas and L.M. Cortina. Taylor and Francis CRC Press.
Hardin, G., 1968. The tragedy of the commons. Science 162, 1243–1248.
Hardner, J., Gullison, T. (HGA), 2007. Independent External Evaluation of the Columbia Basin Water Transactions Program (2003–2006). Hardner and Gullison Consulting, LLC.
Horne, A., Purkey, A., McMahon, T.A., 2008. Purchasing water for the environment in unregulated systems — what can we learn from the Columbia Basin? Australian Journal of Water Resources 1, 61–70.
Hubert, G., Golden, B., McCaulou, S., 2009. Permanent environmental flow restoration through temporary transactions. International Conference on Implementing Environmental Water Allocations. Port Elizabeth, South Africa.
Jensen, A., Good, M., Harvey, P., Tucker, P., Long, M., 2000. River Murray Barrages Environmental Flows: An Evaluation of Environmental Flow Needs in the Lower Lakes and Coorong, a Report for the Murray-Darling Basin Commission.
Jones, G., Hillman, T., Kingsford, R., McMahon, T., Walker, K., Arthington, A., Whittington, J., Cartwright, S., 2002. Independent Report of the Expert Reference Panel on Environmental Flows and Water Quality Requirements for the River Murray, report to the MDBC.
King, M.A., 2004. Getting our feet wet: an introduction to water trusts. Harvard Environmental Law Review 28, 495–534.
Landry, C., 1998. Saving our streams through water markets. Property and Environment Center, Bozeman, MT.
Loomis, J.B., Quattlebaum, K., Brown, T.C., Alexander, S., 2003. Expanding institutional arrangements for acquiring water for environmental purposes: transactions evidence for the western United States. International Journal of Water Resources Development 19, 21–28.
Malloch, S., 2005. Liquid Assets: Protecting and Restoring the West's Rivers and Wetlands through Environmental Water Transactions. Trout Unlimited.
MDBMC, 1998. Murray-Darling Basin Cap on Diversions — Water Year 1997/98.
Meinzen-Dick, R., 2007. Going beyond Panaceas special feature: beyond Panaceas in water institutions. Proceedings of the National Academy of Sciences 104, 15200–15205.
Meinzen-Dick, R., Bruns, B.R. (Eds.), 2000. Negotiating Water Rights. Vistaar and Intermediate Technology Publications, London.
Murray-Darling Basin Ministerial Council (Australia), 1995. An Audit of water use in the Murray-Darling Basin Murray-Darling Basin Ministerial Council, [Canberra], ACT.
Murray-Darling Basin Commission, 2006. The Living Murray Environmental Watering Plan 2006–2007. Murray-Darling Basin Commission. MDBC Publication No. 36/06.
National Marine Fisheries Service (NMFS), 2000. Biological Opinion for Federal Columbia River Power System.
National Power and Conservation Council (NPCC), 2000. Columbia River Basin Fish and Wildlife Program: a Multi-Species Approach for Decision Making. Council Document 2000–19.
Neuman, J., 2004. The good, the bad, and the ugly: the first ten years of the Oregon Water Trust. Nebraska Law Review 83, 432.
Neuman, J., Chapman, C., 1999. Wading into the water market: the first five years of the Oregon Water Trust. Journal of Environmental Law and Litigation 14.
Neuman, J., Squier, A., Achterman, G., 2006. Sometimes a Great Notion: Oregon's Instream Flow Experiments Environmental Law, vol. 36, pp. 1125–1155.
Nias, D.J., D'Santos, P.A., 2009. Quenching the thirst — implementing environmental flows in the Murray Valley, New South Wales, Australia. Proceedings of the International Conference on Implementing Environmental Water Allocations. Port Elizabeth, South Africa.
Olson, M., 1965. The Logic of Collective Action. Harvard University Press.
Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.
Pilz, D., 2006. At the confluence: Oregon instream water rights in theory and practice. Environmental Law Journal 36 (4).
Poff, N.L., Richter, B., Arthington, A., Bunn, S., Naiman, R., Kendy, E., Acreman, M., Apse, C., Bledsoe, B., Freeman, M., Henriksen, J., Jacobson, R., Kennen, J., Merritt, D., Olden, J., Rogers, K., Tharme, R., Warner, A., 2009. The Ecological Limits of Hydrologic Alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology.
Postel, S., Richter, B., 2003. Rivers for Life: Managing Water for People and Nature.
Productivity Commission, 2006. Rural Water Use and the Environment: The Role of Market Mechanisms, Research Report, Melbourne, August.
Rose, C., 2002. Common property, regulatory property, and environmental protection: comparing community-based management to tradable environmental allowances. In: Ostrom, E., Dietz, T., Dolsak, N., Stern, P., Stonich, S., Weber, E. (Eds.), Drama of the Commons. InNational Research Council.
Saliba, B.C., Bush, D., 1987. Water markets in theory and practice. Market transfers, water values, and public policy (Westview studies in water policy and management, No 12).
Sax, J.L., Thompson Jr., B.H., Abrams, R.H., Leshy, J., 2006. Legal Control of Water Resources: Cases and Materials. West Publishing Company.
Scarborough, B., Lund, H., 2007. Saving our streams: harnessing water markets. Property and Environment Center, Bozeman, MT.
Scientific Reference Panel (SRP), 2003. Ecological Assessment of Environmental Flow Reference Points for the River Murray System, interim report prepared by the Scientific Reference Panel for the Murray-Darling Basin Commission.
Siebert, E., Young, D., Young, M., 2000. Market-based opportunities to improve environmental flows: a scoping paper. Natural Resource Management Economics. No. 00_004, Policy and Economic Research Unit. CSIRO Land and Water, Adelaide, Australia.
Slaughter, R.A., Wiener, J.D., 2007. Water, adaptation, and property rights on the Snake and Klamath rivers. Journal of the American Water Resources Association 43 (2), 308–320.
Stillwell, D., 2007. Gone to the Well Once too Often: The Importance of Groundwater to Rivers in the West. Trout Unlimited. Western Water Project.
Thompson Jr., B., 2000. Markets for nature. William and Mary Environmental Law and Policy Review 25, 261.
Thoms, M., Suter, P., Roberts, J., Koehn, J., Jones, G., Hillman, T., Close, A., 2000. Report of the River Murray Scientific Panel on Environmental Flows. River Murray-Dartmouth to Wellington and the Lower Darling River. Murray-Darling Basin Commission, Canberra.
Tietenberg, T., 2002. The tradable permits approach to protecting the commons: what have we learned? In: Ostrom, E., Dietz, T., Dolsak, N., Stern, P., Stonich, S., Weber, E. (Eds.), Drama of the Commons. National Research Council.
Tuckwell, H.T., 1984. Transferability of water rights in south Australia. Proceedings from the joint AWRC and AAES Seminar on Transferable Water Rights, pp. 65–84.
Upper Deschutes Watershed Council (UDWC), 2009. Whychus Creek Restoration Monitoring Plan. Upper Deschutes Watershed Council, Bend, OR.
Van Dijk, A., R. Evans, P. Hairsine, S. Khan, R. Nathan, Z. Paydar, N. Viney, and L. Zhang. 2006. Canberra: Murray Basin Darling Commission.
Washington Department of Ecology and Washington Water Trust (WDOE and WWT), 2007. Mitigation Guide for Future Outdoor Water Use in the Walla Walla Basin. Publication No. 07-11-032. Washington Department of Ecology.
Willey, Z., 1992. Behind schedule and over budget: the case of water, markets, and the environment. Harvard Journal of Law and Public Policy 15, 391–425.