# River Conservation
# Challenges and Opportunities

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## Chapter 12 Offprint

# The Role of Science in Planning, Policy and Conservation of River Ecosystems

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# CHAPTER 12

# The Role of Science in Planning, Policy and Conservation of River Ecosystems

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> *So many of the big issues facing society are* science-intensive, *and beneficial outcomes are unlikely unless science can be actively engaged in the development and assessment of appropriate policies. Climate change, over-allocation of water, endangered species issues as well as a raft of medical issues are all science-intensive issues where factual knowledge from science intersects with strongly held values.*
>
> PETER CULLEN, 2006

River conservation inevitably involves policy and planning with parties with disparate points of view. Successful river conservation needs informed science and the involvement of scientists. The California Delta and the Murray-Darling Basin are provided as current examples where science, policy, and planning are at the forefront for difficult river conservation decisions.

## 12.1. Science for river conservation

Rivers serve as the chief source of renewable freshwater for humans and contain some of the highest levels of biodiversity on Earth. Threats to rivers have become severe in many regions of the world for both securing human water supply needs and maintaining aquatic biodiversity (Vörösmarty et al. 2010). This dual challenge to rivers has resulted in nearly 80% of the world's population being exposed to high levels of threat to water security with 65% of riverine habitats classified as moderately to highly threatened. Changes in human population demographics and global economic activity in the coming decades will be predominant factors impacting future water supply and aquatic biodiversity (Vörösmarty et al. 2000). Threats to river biodiversity can be categorized into impacts from overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion by non-native species (Dudgeon et al. 2006). Threats to water supply include water pollution, salinization, and human-induced climate change. Meeting ecological and societal needs for freshwater is one of the grand challenges of the 21st century (Jackson et al. 2001; Baron et al. 2002).

Jury and Vaux (2005) argue forcefully for the critical role science must play in addressing the world's water problems brought on by intensifying freshwater scarcities, growing populations, and developing economies. Two challenges for the effective use of science in water resource management are 1) applying contemporary and well-integrated knowledge of water resources in management and 2) planning and doing a better job of communicating with and educating water managers, decision makers, and the public. Water resources are often managed in a fragmented way (Jury and Vaux 2005). Examples include ignoring essential interrelatedness of ground and surface waters, failure to acknowledge crucial connections between water quality and water quantity, policies encouraging ground water overdraft, promoting short-sighted and wasteful agricultural water-use practices, and ignoring substantial benefits (ecosystem services) that flow from

**Box 12.1**

## Planners, policy makers, politicians and decision makers

Four groups, along with scientists, play critical roles in determining the fate of rivers.

**Planners** coordinate diverse stakeholder groups to develop broad visions in the form of plans. They conduct qualitative and quantitative analyses and synthesize information to inform plan development.

**Policy makers** policies, which are purpose-driven courses of action. Public policy makers are generally government-appointed officials and may or may not be politicians.

**Politicians** determine policy decisions and are generally active in government. Politicians are often government policy makers.

**Decision makers** include managers charged with implementing projects, plans and policies. Policy makers also make decisions relevant to river management.

well managed and maintained ecosystems. Key to more successful management, planning, and communication is better understanding of the biological systems and processes that influence and are influenced by water availability. Extending scientific knowledge into the social sciences that consider human behaviour also is crucial for water resource management in the 21st century.

Likens (2010) asks, does evidence-based science drive environmental policy? This question is being tested in ongoing management decisions, planning efforts, and policy development for river conservation and restoration worldwide. Likens (2010) describes how human-accelerated environmental change requires better communication among scientists, decision makers, policy makers, the media, and the public. Long time periods may occur between detecting environmental problems and acting to alleviate those problems. Unassailable data, good communication skills, ethical integrity, the opportunity to communicate with planners, policy makers, politicians, and decision makers, knowledge of planning and policy, and perseverance are key attributes for effective scientific input into river conservation. Science can provide context and understanding, establish a framework for evidence-based policy and management, and guide the development of solutions through monitoring and synthesis, but science is not an absolute guarantee for understanding every impact of river restoration and conservation or a means to remove all uncertainty from the decision-making process. Science cannot solve all the problems in complex natural resource management challenges like the conservation and restoration of rivers, but science should provide the reliable knowledge base upon which decisions can be made. Good science, synthesized and interpreted well and communicated clearly, allows informed decisions by planners, policy makers, politicians, and decision makers.

There are numerous challenges for sustainable management of rivers throughout the world. In some regions, political paradigms are changing away from river development to river conservation and river restoration. In other regions, river development remains a central component of planning for feeding and clothing growing populations and providing power for emerging economies. In all cases, however, the role of science in setting policy, guiding planning, and influencing management is much debated and discussed. This chapter focuses on the role of science in policy, planning, and management of river ecosystems with a focus on our experiences in these arenas in the United States and Australia.

## 12.2. The policy, planning and management arenas

In the worlds of public policy, environmental planning and water management, there are many expectations for what roles science can fulfil and what expectations science can meet. These expectations vary based on the political climate, including different and often competing government agencies, the spatial and temporal scales of the river resources and the complexity of the issues. Science is often inserted into the policy, planning and management arenas through major policy decisions (i.e. mandates or laws), regional planning decisions and management actions that can range in scale from local to national. Often, the role of scientists is managing expectations from planners, policy makers, politicians, and decision makers as to the extent and way science can assist decisions given available data and defining the scope of the problems to be addressed.

Science can be inserted into major policy decisions through national or regional government mandates for the purposes of advising and informing decisions about complex social-ecological systems. These decisions can sometimes result in political and policy actions. Politicians and government officials may utilize science to provide evidence for action and guidance for preventing or rehabilitating a problem. However, creative tension often exists between scientific viewpoints or interpretations and the rationale for action. Around the world, science informs major policy, required by law (e.g. Sullivan et al. 2006a,b; Ryder et al. 2010). Several mandates specifically require the use of "best available science" (BAS) (see Box 12.2).

United States federal law in the mid-1960s first required that science guide decision-making for natural resources management decisions, and the Endangered Species Conservation Act in 1969 imposed a requirement that the "best available scientific and commercial data" be used in listing endangered species (Figure 12.1). In Australia, national policy also requires the use of "best availa-

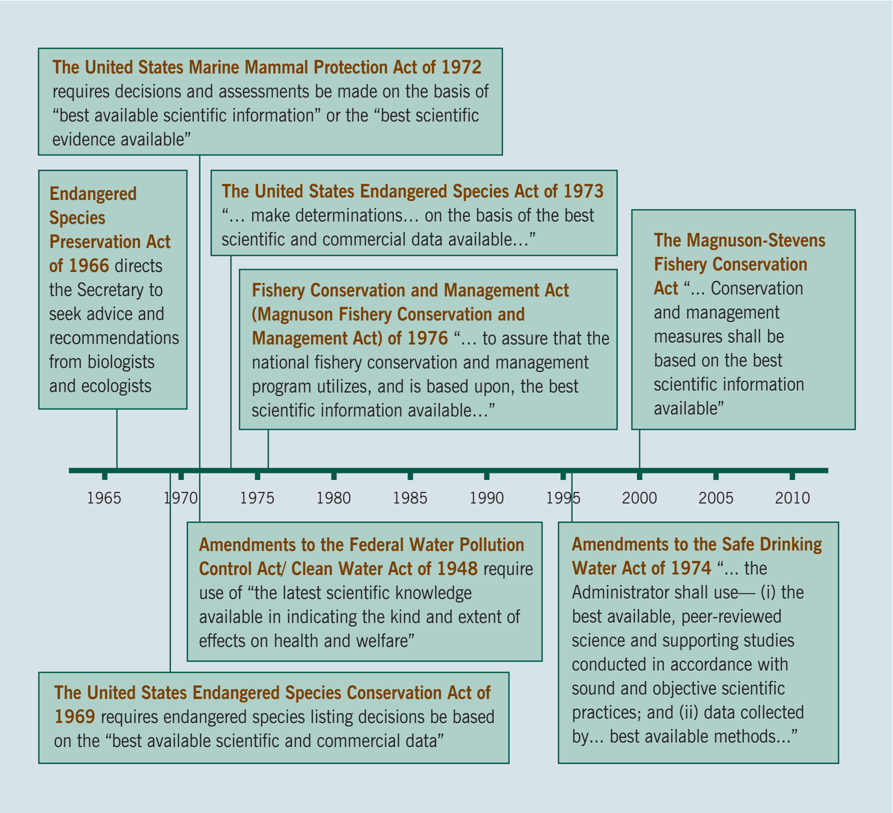
**Box 12.2**

### "Best available science"

The term "best available science" (BAS) is used widely in national, state, and local policies around the world. Its definition continues to be debated among scientists and decision makers and has become a premise for litigation. Several efforts exist to develop criteria for best available science. In 2004, there was acknowledgement that guidelines and criteria must be defined for best available science in natural resource management in the United States (National Research Council 2004). Recommendations included establishing procedural and implementation guidelines to govern the production and use of scientific information. These guidelines were based on six broad criteria: 1) relevance, 2) inclusiveness, 3) objectivity, 4) transparency and openness, 5) timeliness, and 6) peer review.

ble science”. The Australian Water Act of 2007 that created the Murray-Darling Basin Authority (MDBA) and specified the development of a Basin Plan for the sustainable management of the Murray-Darling Basin states, “the Authority is to determine the volume of water required to maintain and restore environmental assets and functions, using best available science and the principles of ecologically sustainable development”.

Planning efforts for rivers (i.e. balancing river water supplies for human and ecosystem needs) are often a product of disparate legislation required to manage a variety of natural resources. Multiple plans are often developed (particularly when multiple agencies are involved) that conflict with little thought on how to reconcile the multiple goals of the various plans. Complex and competing demands on river resources provide excellent examples where competing planning efforts aimed at maximizing river resources for human and ecosystem needs are developed with competing goals, objectives, and assumptions (see examples below). This leads to problems of planning integration and issues of



**The United States Marine Mammal Protection Act of 1972** requires decisions and assessments be made on the basis of “best available scientific information” or the “best scientific evidence available”

**Endangered Species Preservation Act of 1966** directs the Secretary to seek advice and recommendations from biologists and ecologists

**The United States Endangered Species Act of 1973** “… make determinations… on the basis of the best scientific and commercial data available…”

**Fishery Conservation and Management Act (Magnuson Fishery Conservation and Management Act) of 1976** “… to assure that the national fishery conservation and management program utilizes, and is based upon, the best scientific information available…”

**The Magnuson-Stevens Fishery Conservation Act** “… Conservation and management measures shall be based on the best scientific information available”

**Amendments to the Federal Water Pollution Control Act/ Clean Water Act of 1948** require use of “the latest scientific knowledge available in indicating the kind and extent of effects on health and welfare”

**Amendments to the Safe Drinking Water Act of 1974** “… the Administrator shall use— (i) the best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices; and (ii) data collected by… best available methods…”

**The United States Endangered Species Conservation Act of 1969** requires endangered species listing decisions be based on the “best available scientific and commercial data”

**Figure 12.1:** *A chronological summary of science requirements found in major environmental laws in the United States*

scale and complexity in dealing with uncertainty. Science is often inserted into these planning efforts in order to assess the sources and magnitude of the uncertainty when dealing with complex and competing goals. Environmental policy is most effective when scientific uncertainty is incorporated into the decision process as *knowledge* rather than ignorance (Bradshaw and Borchers 2000); this helps policy makers assess where uncertainty lies and its seriousness. For example, numeric values can be presented as ranges of likely values, and assessments and conclusions can be rated as to the degree of certainty (e.g. high, moderate, or low). In general, uncertainty increases with increasing complexity, spatial and temporal scale and system variability – all features of most river basins.

Science also can inform conceptual models that provide a rationale for selecting plans and actions likely to achieve their intended goals. An excellent example for the use of conceptual models in river conservation and restoration is the South-East Queensland Environmental Health Monitoring Programme (EHMP) in Australia (Bunn et al. 2010). EHMP uses conceptual models and objective testing utilizing 16 indicator metrics to diagnose probable causes of river degradation arising from multiple stressors. The approach taken in this programme leads to more targeted management for river conservation and rehabilitation. Key lessons from this successful programme include the importance of a shared common vision, the involvement of committed individuals, a cooperative approach to problem solving, and defensible science with effective communication.

Managing the resources of rivers, through the implementation of plans, programs and projects, involves regularly confronting uncertainties. These uncertainties are inherent when managing complex systems. One role of science in management is to help define a process for acting under uncertain conditions (Likens 2010). These processes include Strategic Adaptive Management (Chapter 13) which includes targeted research to address specific objectives and uncertainties, monitoring feedback loops, and synthesizing current understanding for improving future management actions. Science also plays a key role in building tools (e.g. conceptual models, predictive models, scenario testing, and decision support systems) for guiding management decisions under uncertainty (Bradshaw and Borchers 2000). Uncertainty is commonplace in complex human and natural systems such as the economy, public health, and climate change and is not simply the domain of water resource management or environmental issues.

## 12.3. Inserting science into policy, planning and management

Insertion of science into policy, planning and management is essential for informed decision making but can yield both positive and negative results. While providing objective information, science can become value-laden in how it is inserted into decision-making. This can lead to science being used to promote one agenda over other competing agendas ("combat science") and as grounds for litigation (Hanak et al. 2011). How, when and what science is used to inform policy, planning and management decisions affects the perception and reality of how well science helped to inform the actions taken and its value in decision making. This is not an argument against the use of science in decision making concerning such challenging topics as river conservation and restoration but a caution that how science is summarized, packaged and communicated affects how science is used for making management decisions.

High value is normally placed on the quality of the science used to inform policy, planning and management decisions (Box 12.2). Independent scientific peer review helps ensure that best available scientific knowledge for decision or policy making processes is applied in an objective, transparent and scientifically valid manner, especially when the decisions are controversial or associated with high uncertainty (Meffe et al. 1998). Independent open review of programs, plans and products to promote the use of best available science in policy, planning and management enhances the chances that high quality science will be incorporated into decision making. Monitoring and evaluation also provide objective scientific support for decision makers. These programs build the scientific knowledge base to answer complex questions in river policy, planning and management. Coupling a strong monitoring program with a well-designed synthesis and integration effort (e.g. Strategic Adaptive Management, Chapter 13) improves the likelihood that high quality science will inform policy, planning and management of river ecosystems.

We have had considerable experience in working at the interface between science and policy for the management of rivers in two high-profile regions in the United States and Australia. The California Delta is the confluence of the Sacramento river and the San Joaquin river, and the delta is the heart of the largest water supply system in the world. The Murray-Darling Basin is the focus of substantial agricultural production in Australia and often called the "bread basket" of Australia. We focus on the role of science in planning, policy and management for these two catchments while acknowledging similar challenges in riverine landscapes worldwide.

## 12.4. Science and policy in the California Delta

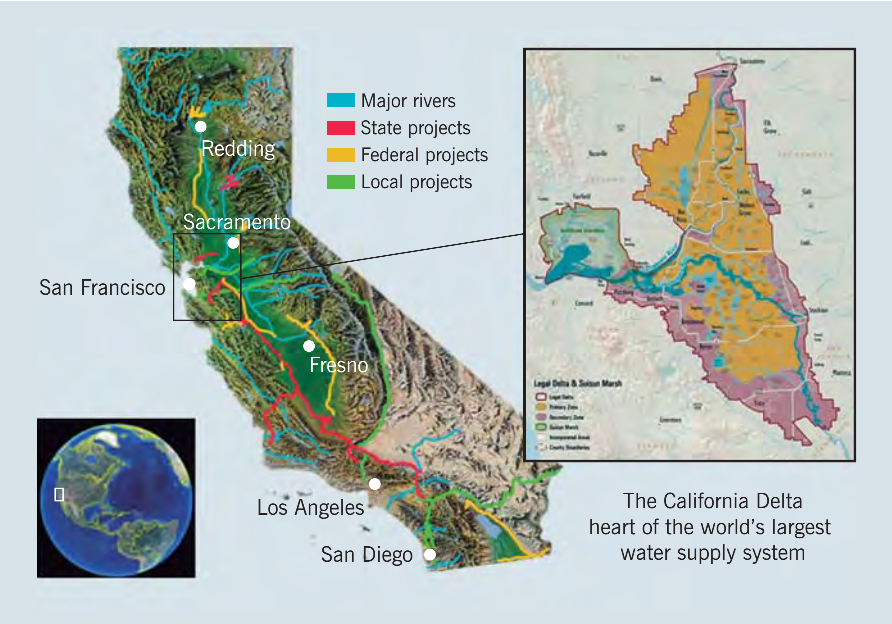
The California Bay-delta (Delta) catchments encompass about 40% of California and the catchments for the rivers receive about 50% of the annual precipitation that the state of California receives. The Delta is one prominent example where balancing water supply needs and sustaining biodiversity is difficult (Figure 12.2). The Delta is the heart of the largest water supply system in the world (Dahm 2010). Precipitation in northern California and the Sierra Nevada flows into the Delta, and some of this water is pumped from the Delta by two large pumping facilities for use by urban and agricultural areas of central and southern California. The Delta ecosystem provides some of the water supply for ~25 million Californian residents, irrigates about one million hectares of farmland that accounts for ~45% of the fruits and vegetables grown in the United States, and is home to ~50 species of threatened or endangered plants and animals. The Delta also supports a local rural economy and is home to about half a million people.

Approximately 80% of the water flowing into the Delta derives from the Sacramento River, 15% from the San Joaquin River, and 5% from rivers that enter the

**Figure 12.2:** *Part of the California Delta, confluence of the Sacramento and San Joaquin rivers*

Delta from the east (Figure 12.3). Water quality is variable in the various source waters with generally higher water quality coming from the Sacramento River and the eastern rivers than from the San Joaquin where agricultural runoff dominates flows during much of the year. Interannual variability in precipitation in California is the highest of any state in the United States (Dettinger et al. 2011). This leads to highly variable natural flows in the rivers, and significant total annual precipitation derives from intense brief oceanic storms ("atmospheric rivers") sweeping in from the subtropical Pacific Ocean. Therefore, water supply is strongly linked to floods in many rivers of California and commonly comes with a few high intensity storms. This highly variable supply of precipitation and spatially variable distribution of water has been the impetus for water works that reallocate and export water from the Delta. Exports from the Delta have increased from around 1,200 gigalitres (GL) in the 1940s to ~6,200-7,400 GL in recent decades (Culberson et al. 2008). One gigalitre is the same as one cubic hectometre, one million cubic meters, or 811 acre feet. Conservation planning for the Delta focuses on 1) water exports (amount, timing of withdrawal, hydrodynamic impacts, and effects on water quality), 2) the most effective way to convey water (through, around, or beneath the Delta), and 3) river and marsh restoration.

Critical issues and drivers of change in the current Delta include climate variability, water quality, land subsidence, sea-level rise, earthquakes, invasive spe-



The California Delta
heart of the world's largest
water supply system

**Figure 12.3:** *Location of the California Delta at the confluence of the Sacramento and San Joaquin rivers*

cies, human population growth, and climate change. For example, the islands of the central Delta have subsided up to nine meters below sea level, and they are threatened by catastrophic flooding from sea level rise and earthquakes. Climate change scenarios for this century for the basin predict warmer temperatures of 1.5 to 4.5 °C, a one-third loss of snowpack in the Sierra Nevada by 2050, and higher and flashier winter river flows and lower summer flows with longer periods of low flows (Cayan et al. 2008). The recent dramatic decline of open water (pelagic) fish species in the Delta has drawn political interest and spurred considerable research on water movement, food webs, nutrients, contaminants, and habitat. This scientific research is now being incorporated into major planning documents to guide restoration of key attributes of the Delta while maintaining needed water supplies for California.

## 12.5. The Delta Reform Act of 2009

Recognition of the declining condition of the Delta and the need for increased reliability of water supply culminated in new State of California legislation (November 2009) aimed at addressing these dual challenges. The Delta Stewardship Council (Council) was created through this legislation to achieve the state mandated "coequal goals" for the Delta. "Coequal goals" is defined by state statute as the two goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem." In addition, the statute requires that "the coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place."

The Delta Reform Act of 2009 (Act) established statutes for the role of science in the California Delta. A Delta Independent Science Board with up to ten members was established to provide scientific oversight for research in the Delta. The Delta Science Program was placed under the Council with a vision that Delta water and environmental policy is founded on the highest calibre science and a mission to provide the best possible scientific information for water and environmental decision-making in the California Delta. This is to be accomplished through supporting research, synthesizing scientific information, facilitating independent peer review, coordinating science activities, and communicating science. Statute also requires that adaptive management be used in decision-making and developing policy. The Act defines adaptive management as "a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives." A concerted effort has been made to insert science into the planning, policy and management components of the Act.

## 12.6. The Delta Plan

The goals set out in the Delta Reform Act of 2009 are to be met through the Council's development and adoption of a Delta Plan. The Delta Plan is to lay out policies, recommendations, and management goals for the Delta through 2100. The Delta Plan will be a "living document" with periodic updates and use adaptive management principles to guide planning, implementing and revising the plan. Key components of the Delta Plan require substantial scientific input. The Delta Science Program took the lead on chapters and sections concerning 1) science and adaptive management, 2) ecosystem restoration, and 3) water quality. The dual challenge of providing water security and decreasing threats to aquatic biodiversity are at the core of this new plan.

The Delta Science Program provides scientific input to decision makers charged with adopting the new Delta Plan. The Program takes an ecosystem-based approach to supporting research in the Delta with a commitment to high quality science, communicating science to a diverse audience, promoting ecosystem-based management and adaptive management, and carrying out rigorous evaluation of past and future projects. The Delta Science Program also attempts to provide independent scientific oversight, integrate across program and agency issues and mandates, ensure that decision makers have reliable information concerning complex Delta issues, and play the role of "honest broker" among competing interests. This involves the convening of public workshops to discuss contentious issues, the constituting of independent review panels to openly review scientific documents, and support of targeted science to address key uncertainties affecting policy decisions. Science support for the current planning exercise has particularly focused on linking emerging scientific understanding in the Delta to responsive policies and recommendations for flow objectives, delimiting best available science, adaptive management, ecosystem restoration, and water quality (http://www.deltacouncil.ca.gov/delta-plan).

The Delta Plan is being developed through a transparent and collaborative process (Figure 12.4). When adopted, the plan will have undergone seven public drafts. Following each Council-staff prepared draft, the public was given considerable opportunity to comment on the Delta Plan through meetings of the Council, written comment letters, public workshops and agency stakeholder meetings. To ensure that the best science is used in the development of the

**Figure 12.4:** *Public meeting of the Delta Stewardship Council. Five of the seven council members are shown*

Delta Plan, the Delta Independent Science Board was asked to provide scientific review on early drafts of the plan. The Council will vote to adopt the final draft of the Delta Plan in the spring of 2013. Once the Delta Plan is adopted and approved as State of California regulation, the Council will have the legal responsibility and authority to implement the plan.

Implementation of the Delta Plan will continue to rely on the use and development of best available science. Current drafts of the Plan commit the Delta Science Program to play a key role in 1) the continued development of science-based performance measures for the Delta Plan, 2) the development of landscape-scale conceptual models for informing restoration decisions in the Delta, 3) synthesis and evaluation along with communication of science to inform adaptive management of the Delta Plan, 4) the coordination of workshops to inform policy decisions related to Delta environmental stressors, and 5) the development of a Delta Science Plan that utilizes an open and collaborative process in developing an institutional and organizational structure for conducting Delta science activities in an efficient, collaborative, and integrative manner.

The Delta and the rivers that flow into the Delta are at a crossroad. The Delta is changing rapidly as human population growth, invasive species introductions, the risk of earthquakes, increasing sea level rise, continued land subsidence, deteriorating water quality, altered hydrodynamics and a changing climate constitute multiple stressors upon the system. Critical questions such as the best way (environmentally and economically) to convey water through (as is currently done), around (involving a canal that diverts water before reaching the Delta), or beneath (large tunnels transporting water underground) the Delta and whether habitat restoration can effectively mitigate for water exports remain unanswered. A new governance structure (the Delta Stewardship Council) with a science program and an independent science board was created by legislation in November of 2009. The Delta Stewardship Council must institute policies and make recommendations to achieve the coequal goals of a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. As required by law, the Council will use BAS and a science-based adaptive management strategy for decisions on ecosystem restoration and water management. The planning process is actively ongoing with long-term conservation of the Delta ultimately in the balance.

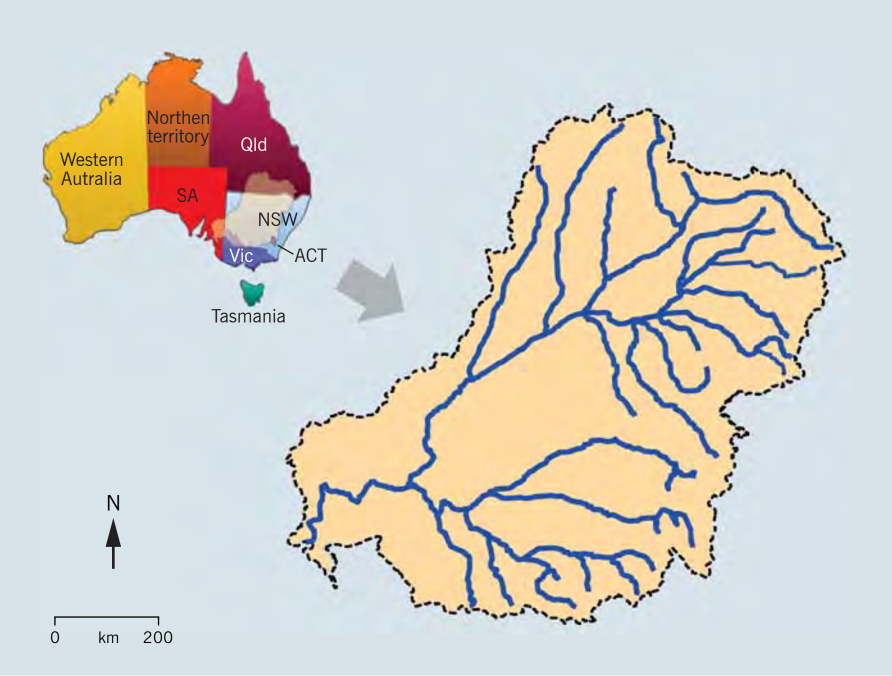
Scientists interested in conserving and restoring rivers must be more capable at working the interfaces between science, policy, planning and management

## 12.7. Science and policy in conservation of the Murray-Darling Basin

The Murray-Darling Basin (MDB) drains just over a million square kilometers of south-eastern Australia and is divided among five different states (Figure 12.5), each with different systems of water entitlements and management. Some two million people live in the MDB, which supplies most of the water for another million people downstream in South Australia. Earning it the name “Australia’s bread basket”, the MDB contributes some US$15 billion of agricultural produce each year in Australia, of which US$5.5 billion is derived from irrigation (~45% of national irrigation produce; MDBA 2010). However, scientists have shown that much of the system is in poor health (see Sustainable Audit section later) and many catchments are grossly overallocated (in some cases, over 100% of the entitled water has been allocated for human use). Public and political awareness of the severity of the MDB’s plight peaked after a decade-long drought (ending in 2010) on top of some two centuries of unsustainable river exploitation by European settlers. Why did it take so long to react to the environmental damage and how can the ecological resources of the Basin be restored and conserved?

Since Federation in 1901, state governments have squabbled over allocation of water in the system. Not surprisingly, states in the upper reaches have been accused of reducing water resources for downstream states. State governments used water as a tool to promote rural community growth and there was little

**Figure 12.5:** *The Murray-Darling Basin (shaded) comprises two main rivers – the Darling River to the north and the Murray River to the south – flowing southwest and draining the states of Queensland (Qld), New South Wales (NSW), the Australian Capital Territory (ACT), Victoria (Vic) and South Australia (SA)*



concern about environmental issues or conservation. Sharp increases in diversions in the second half of the twentieth century intensified competition among water users and caused serious environmental problems. State governments stepped back from promoting irrigation interests and, instead, adjudicated water usage among competing stakeholders. In the meantime, the Commonwealth government sought to manage the basin as a whole, requiring a policy instrument that would coordinate the two levels of government. This spawned the Council of Australian Governments in 1992 whose deliberations led to the National Water Initiative (NWI) in 2004. The NWI, among other actions, sought to cap extractions at 1994 levels. However, when these agreed reforms failed to deliver sustainability, the Water Act 2007 was enacted.

This Act created the Murray-Darling Basin Authority, a body charged with developing and implementing a Basin Plan as an integrated approach to manage the MDB's water resources. Central to the plan is a "sustainable diversion limit" (SDL) set for the whole basin, with diversion limits also set for sub-basins. Best available science was explicitly requested to help set these limits, taking into account environmental demands, water quality and salinity as well as changes in runoff predicted as a result of climate change, bush fires and new agricultural activities. Working within the Basin Plan's policies, States are required to develop water management plans for approval by the Federal Minister but state governments still retain control over their water resources.

Although many scientists had worked on the ecology of the MDB for decades, there was little catchment-wide research and coordination among individual scientists was limited. Often, scientific research was commissioned in a reactive way. For example, when a 1,000-km long blue-green algal (cyanobacteria) bloom threatened farming communities along the Darling river in 1991, research projects on blue-green algae burgeoned. Only when "science champions" such as Professor Peter Cullen (Box 12.3) coordinated efforts within cooperative research centers while also wielding considerable political influence with state and federal governments did the results of scientific research start to effectively guide policy development and river basin conservation. Other champions, such as Professor Richard Kingsford, coordinated groups of scientists to become involved in workshops on rivers of conservation significance (e.g. the Paroo, Chapter 13), prepared consensus views on environmental issues co-signed by fellow scientists (e.g. scientific statements on the Basin Plan, http://www.wetrivers.unsw.edu.au/2012/04/scientific_statement_pbp/) and appeared frequently in the media, promoting the role of good science in river conservation and management.

## 12.8. The Sustainable Rivers Audit – Murray-Darling Basin

In 2004, the first formal coordinated audit of the rivers of the Murray-Darling Basin (MDB) was carried out, supervised by a panel of four independent ecologists. This program, the Sustainable Rivers Audit (SRA), assessed five ecosystem components: hydrology, physical form, vegetation, macroinvertebrates and fish (methods described fully in Davies et al. 2010). Metrics derived from assessments of these components in 23 rivers of the MDB confirmed the dismal state of the system. Only one river (the Paroo, Chapter 13) was rated in Good Health and only two other systems were deemed in Moderate Health. The rest were assessed to be in Poor or Very Poor Health (Davies et al. 2010).

These data were crucial for scientists, managers and policy makers in their application of the Water Act 2007 to determine sustainable diversion limits for each of the rivers of the MDB and underpinned what is known as the Basin Plan. The Basin Plan is a system-wide attempt to protect and restore the ecological and other values of water-dependent ecosystems of the MDB so that the ecosystems remain healthy in the face of climate change. To achieve this, "long-term average Sustainable Diversion Limits" (SDLs) were derived from the hydrological and ecological data, combining assessments of surface and

**Box 12.3**

## Peter Cullen – shining example of a scientific champion

**Figure 12.6:** *Professor Peter Cullen, one of Australia's greatest science champions*

Professor Peter Cullen (1943-2008) was an exceptional champion of water reform in Australia. His personal attributes of great humanity, a powerful work ethic, scientific understanding, political awareness, oratory skill and dry humour allowed him to influence Prime Ministers and state Premiers, irrigators and farmers, scientists and journalists. Early on, he acknowledged the "turbulent boundary" between scientists and managers (Cullen 1990) and devoted the next two decades of his life to improving dialogue between two groups whose ideologies, backgrounds and time frames often differed. Although he was a strong advocate of the role of science in water resource management (for example, founding and directing the Cooperative Research Centre for Freshwater Ecology), he once said: "Scientists commonly hold strong values about desirable outcomes, and should be welcome in the political debates as society grapples with the various issues. However, they should not expect their scientific standing gives them any special right to decide value questions for society. Their science needs to inform the debate, not replace the debate" (Cullen 2006). He mentored many scientists in how to become usefully involved in political debates and discussions, urging them to make a more effective contribution in situations where all interests do not necessarily welcome the scientists' messages. Most of all, he constantly argued that scientists have an obligation to ensure that their knowledge and insights are available to the community that funds them.

Peter Cullen successfully bridged the gaps between science, resource management and policy. He saw the "big picture" and not only described the problems but suggested solutions. He was an influential member of the powerful Prime Minister's Science, Engineering and Innovation Council, and he proposed many of the research and policy threads in the Australian National Water Initiative. He won many prestigious international awards (summarized in Lake et al. 2010) for his work in water reform and environmental management. Most importantly, he was a consistent and effective champion for the role of rigorous science in water resource management, policy and the conservation of freshwater biodiversity (e.g. Cullen 2003).

groundwater resources as well as the SRA results. The Act specifically requires the Basin Plan to identify risks to the condition and availability of the MDB's water resources and to identify strategies to manage those risks. A guide to the proposed Basin Plan was released in October 2010 and met with instant strong and demonstrative opposition by irrigators in some quarters (Figure 12.7) who predicted financial ruin.

Even before this release, in response to concerted lobbying by vested interests, the recommendations for the environment's share of the diversions were reduced from an initial estimate of 7,600 GL per year down to 3,000-4,000 GL per year (in October 2010) for public discussion. The guide to the proposed Basin Plan suggested that the full range of natural variability would be encompassed within 3,000 – 7,600 GL per year. However, the strong reaction to the suggested SDLs led to a reassessment by the MDBA. In November 2011, after considerable further consultation, two parliamentary inquiries and resignation of the Chair of the MDBA Board and Chief Executive Officer, the MDBA produced the proposed draft Basin Plan (http://www.mdba.gov.au/draft-basin-plan/draft-basin-plan-for-consultation). The media release (28 November 2011) stated: "More recent and robust modelling has shown that key environmental objectives can be met with a lower volume than the range suggested in the Guide" and so they advocated 2,750 GL per year with a seven-year period (to 2019) to implement this volume. Almost half that volume

**Figure 12.7:**
*Angry irrigators in Griffith, New South-Wales, burn a copy of the "Guide to the Draft Murray-Darling Basin Plan Volume 1" after it was released in October, 2010*

had been obtained by water buybacks and improved infrastructure by the end of 2011.

Although there is general agreement that the MDB is in poor ecosystem health, the setting of SDLs upset many irrigators objecting to cutbacks on their water allocations, even though these would be paid for by taxpayers. SDLs are to be achieved by a combination of water buyback and investment in infrastructure, and the Australian government has made a commitment to "bridge the gap" between current levels and proposed levels of water diversions without affecting entitlement or allocation reliability (http://www.mdba.gov.au/draft-basin-plan/draft-basin-plan-for-consultation). By 2019, it is expected that buybacks and infrastructure investments will have achieved the reductions in diversions. To support the plan, the Australian government committed over US$9 billion to the MDB up to 2019.

The Water Act 2007 stipulates that SDLs will reflect an environmentally sustainable level of water removal. Scientific advice underpins determining how much water the ecosystem "needs", when it needs it (i.e. seasonal flow regimes) and how these amounts will differ from year to year in response to climate change and natural annual variability in flows. Socioeconomic studies have also been carried out to ascertain the likely effects of different SDLs on various Basin communities. Results of these studies indicated that the proposed SDLs would not have an unduly harsh impact on some local human communities and, where impacts were likely, what strategies would ease the transition. There was also an assessment of the value of ecosystem services improved by the return of flows, estimated to be some US$3-8 billion (CSIRO 2012). The most recent modelling studies (Young et al. 2011) consider the science to be adequate and argue that 2,800 GL per year would be an appropriate compromise. However, many scientists remain sceptical because they do not believe this amount of water is adequate to fulfil the ecosystem's needs, especially in the face of projected climate change and human water demands in this largely dryland system (Figure 12.8).

## 12.9. Interacting with managers and policy makers from an Australian perspective

In Australia's Murray-Darling Basin, scientists, managers and policy makers are grappling to find a new way to interact. After two decades of "engagement" under various natural resource programs, the Millennium Drought or "big dry" (*sensu* Prowse and Brook 2011) highlighted that the country's river management plans, policies and best available science had not coalesced to prevent

**Figure 12.8:**
*Much of the Murray-Darling system, such as this section of the Darling River, flows through arid and semiarid country. The water is typically turbid and natural water levels can vary greatly between long periods of low or zero flow alternated by irregular huge floods*

massive biodiversity loss. Large tracts of red gums were killed throughout the basin by lack of water, and internationally important wetlands were parched without some natural flows so that aquatic groups such as fish, water plants and waterbirds declined sharply in abundance (Kingsford et al. 2011). Water Sharing Plans were suspended in many NSW rivers when the rules of allocation to water users failed during the long drought (National Water Commission 2009). The plans captured volumes and flood frequency, but did not set maximum limits for the inter-flood interval, the critical dry period between floods.

With opportunities for reform being forged by the Basin Plan and the establishment of the Commonwealth Environmental Water Holder (CEWH) with considerable funding for the buyback of water (US$3.1 billion), the playing field for interaction with scientists is changing. Unfortunately, this is largely driven by who controls science funding. Monitoring of environmental flows is no longer the bastion of state government agencies, with the CEWH contracting scientists to report on outcomes of its environmental water releases. At the same time, government budget cuts in NSW are reducing the state's capacity to meet monitoring and research obligations for rivers. The CEWH has released a framework for monitoring, providing one avenue for debate and coordination. Senior managers from the Murray-Darling Basin Authority (MDBA) and National Water Commission are pushing for greater collaboration among scientists to address complex problems but without a clear investment. However, the freshwater research direction at the Commonwealth (national government) level is uncoordinated and criticised by some as lacking leadership. In response, scientists are organising into clusters to research ecological responses to environmental flows and to tender for monitoring contracts on environmental flows. The days of individual scientists broaching ad hoc research projects with managers and planners have passed.

There is consensus that scientists need to be organised at a broader scale to interact with managers and policy makers, but the nature of this coordination is unclear. Should there be a Commonwealth scientific body to debate and drive collaborative direction? In the past, Land and Water Australia provided a focus for ideas, but the funding programs fostered competition rather than collaboration at a broad scale. Land and Water Australia was abolished late in 2009, leaving a vacuum in science funding. Science and Technology Australia provides an advocacy role for science, but has not stepped into directing or coordinating roles. Could market forces drive scientific consensus if the MDBA and CEWH, for example, set the agenda for broad scale research on multi-stressor problems and demanded collaboration? Ideally, if planning at a basin scale followed a Strategic Adaptive Management framework (Kingsford et al. 2011), interactions between science, management and policy would promote debate and coordinated solutions to the water crisis in the Murray-Darling Basin. A real engagement process (see examples in Chapter 13) could transform the MDBA from an agency “that everyone hates” to an agency that is admired for its leadership by all sectors of society.

## 12.10. Communicating the role of multiple stressors on the MDB system

Without dissent, a policy commitment exceeding US$9 billion to “save the MDB” was announced before the Australian federal election in 2007 although no-one has ever explained where this monetary figure came from. It had bipartisan support at the federal level. Byron (2011) asserts that if anyone had asked in the Commonwealth Parliament in 2007 “Who wants to save the Murray-Darling Basin”, all hands would have risen. However, if the question had been “Does anyone understand the nature of the problems facing the MDB, how we got into this mess, the options for getting out of the mess, how long that will take, how much it will cost, and whose cooperation do we need to succeed”, then Byron suggests that no hand would have been raised. This illustrates that either scientists have done a poor job of communicating the impact of multiple stressors on the MDB or that politicians and managers have been poor listeners – or both.

In an effort to simplify the message for rapid communication, the widely held perception of the "problem" in the MDB is that rivers, wetlands and floodplains are under severe stress and that the cause is excessive extraction of water from the rivers for irrigation. The "solution" is seen in equally simplistic terms: if irrigation extractions are reduced to SDLs and the saved water is re-assigned for environmental purposes, the basin will be restored to a healthy, sustainable system. The pervasive notion is that "all the environment needs is more water" with one corollary seeming to be that "the more water added, the better the environmental outcomes will be". This notion underlies much of the debate about the Basin Plan and because it is half-right, it is hard to refute. Nonetheless, the debate remains critically important and when the number defining how much water will be returned is finally settled, the focus will move to other stressors on the rivers.

More scientists need to be both willing to engage in and be better trained at effective communication with planners, policy makers, decision makers, and politicians

However, environmental decline in the MDB has occurred because of more than just declines in water volumes. There have been changes in the flow regime (seasonal timing and variability of river flows and floodplain inundation), water quality has deteriorated, exotic species (e.g. carp, willows) have invaded the rivers' channels and riparian zones, structures have interrupted flows on floodplains, numerous dams and weirs interrupt the longitudinal dispersal of riverine fauna and flora, and sediment regimes have been altered by inappropriate catchment clearance and land use. Multiple, interacting stressors impact upon the rivers of the MDB and it is impossible to point to a single stressor and claim that it is the main problem.

Scientists have described the multiple stressors repeatedly in unpublished reports, peer-reviewed literature and the popular media. Local governments have spent thousands of dollars attempting to control particular stressors, such as by restoring riparian zone vegetation and decommissioning weirs and dams. Efforts to restore the timing of natural flows and inundation patterns have had some success. However, it is striking that much of the focus of the Basin Plan has been on the SDLs whereas the MDB is afflicted by multiple stressors, some of which are unlikely to be resolved by simply adding more water back into the system. Effective conservation and management of the MDB needs better communication from scientists about the effects and interactions among multiple stressors and how best to ameliorate their collective impacts.

## 12.11. The need for *champions* for improving the role of science in river conservation

Poff et al. (2003) discussed the need for improving the science used for setting flow criteria in river ecosystems. The highly contentious process of determining flow requirements for rivers to achieve desirable ecological outcomes while ensuring reliable water supplies requires new and emerging science. Scientists need to be viewed and accepted as partners at the table with resource managers and other stakeholders in a collaborative process in managing river ecosystems. This way, scientific understanding, management strategies, and societal goals are effectively integrated. Four recommended steps for strengthening the role of science in managing rivers to meet human and ecosystem needs are: 1) large-scale experiments on existing and planned water management projects, 2) collaborative processes involving scientists, managers, and other stakeholders, 3) integration of case-specific knowledge into broader scientific understanding, and 4) forging new and innovative funding partnerships (Poff et al. 2003).

Ultimately, improving the role of science in river conservation requires scientific champions. Peter Cullen epitomizes such a champion in Australia, and he made major contributions to science, policy, planning and management of Australian rivers (see Box 12.3 and Figure 12.6). The success of a scientific champion hinges on having respect and credibility across the entire sector from fellow scientists to the general public, excellent communication skills, and a work ethic that combines sustained effort and persistence with patience and the capacity to be willing to repeatedly contribute to debates at all levels, even the publicly unpopular ones. These traits are rare in any individual, let alone a trained scientist.

Scientific champions typically achieve more when they work as a professional collective. This is because they can draw on a greater range of skills and expertise, and are likely to have a higher public profile. In Australia, Peter Cullen was a founding member of one such collective in 2002. This independent group, calling themselves “The Wentworth Group of Concerned Scientists” (www.wentworthgroup.org), inserted science effectively into conservation and water resource management in Australia through some highly publicized media releases. The Wentworth Group included leading Australian scientists, economists and business leaders with conservation interests. They produced a series of “blueprints” – readable, closely-argued and brief documents that outlined the environmental problems facing Australia’s water resources and explained the causes. These blueprints also presented solutions that would protect river health and Australians’ rights to clean usable water, establish nationally consistent water entitlement and trading systems, and engage local communities to ensure a fair transition.

In 2010, the Wentworth Group produced a blueprint on sustainable MDB diversions (http://www.wentworthgroup.org/uploads/Sustainable%20Diversions%20in%20the%20Murray-Darling%20Basin.pdf). This blueprint drew on the best available science to identify the maximum quantity of water that could be taken from the basin and from the 18 sub-basins, assessing the most cost-effective way to obtain the water while assisting local communities to adapt to the changes in water resources. They concluded that the basin's rivers required two-thirds of their natural flow to be healthy and recommended that the environment's share of the diversions should be 4,400 GL per year (from an estimated average annual end-of-system flow of 12,233 GL per year before European exploitation).

The Wentworth Group's success arose from several factors (Cullen 2006). First, their blueprints used clear and simple language and avoided qualifiers and citations of scientific references. Second, they clearly articulated the problems and linked these to realistic, effective solutions. Third, the key messages remained focused and the group shared a vision to pool their expertise to develop integrated solutions to problems. Fourth, the group was not self-interested or simply calling for more research funding. Fifth, the members of the group were well-recognized in their areas of expertise and had substantial media standing and skills. Finally, the group never claimed that the proposed solutions were the only ones or even the best ones, but they suggested the solutions were effective and invited anyone with better solutions to bring them forward. By writing succinct blueprints instead of detailed treatises, by using media in a timely and skilled way, and by being willing to debate their blueprints widely, the Wentworth Group was extremely successful in inserting science into several complex management and conservation debates in Australia. Champions like Peter Cullen and his colleagues have done much for river conservation and restoration in Australia. Similar champions are currently playing critical roles in river conservation worldwide.

## 12.12. Challenges for inserting science into river conservation

When science is incorporated into planning, policy and management, decisions can also have a large impact on conservation efforts. Inserting science at the outset of planning for river conservation provides policy makers, planners and decision makers with a better understanding of the need for science rather than seeing science as obstructive or slowing the planning and decision-making process. It also is important to communicate the relevance of science and engineering in decision-making to those making river conservation decisions. This may entail repeated, positive and non-confrontational exposure to relevant science (e.g. the Delta Lead Scientist makes regular presentations of relevant and leading scientific papers and findings to policy makers on the Delta Stewardship Council at monthly public meetings). When planners and policy makers see the need for science upfront, they are more likely to seek scientific input. However, demonstrating that science, especially ecological science, provides added value to policy, planning and management decisions can be a challenge for scientists. Ecology concerns itself with relationships between living organisms and their environment, and river ecosystems link climate, hydrology, chemistry, and ecology in ways that can guide good policy and decision-making. Communicating these interactions with good timing and clarity is necessary to the incorporation of current scientific understanding into river management. Science that successfully pushes policy, planning and management forward will acknowledge multiple stressors, point towards well-ordered and manageable steps toward improvement, and provides time points to celebrate situations when science has helped successful river conservation efforts (see Chapter 13).

A key challenge of inserting science into river conservation is access to decision makers and politicians. Sometimes, enabling legislation facilitates scientific input into river conservation and restoration (e.g. the Australian Water Act 2007 and the Delta Reform Act of 2009). The challenge then becomes one of utilizing this access effectively by communicating science in a clear and applicable manner. In other cases, pressure from scientists themselves and the public is necessary to bring scientific information into the decision making process. Democracies have more effectively inserted science into the policy arena with the more open and public institutions that allow due consideration of scientific information. Scientists, however, must realize that the opportunity for input on issues of river conservation and restoration does not guarantee a positive outcome. Decision makers, however, also need to acknowledge that scientific input and application of BAS does not mean repeated solicitation of technical input until the content of that input is finally deemed acceptable. Persistent scientific champions with good communication skills and a broad and interdisciplinary understanding of river ecosystems are most effective in inserting science into policy, planning and management, but science still needs to inform the debate but not replace the debate, as Peter Cullen perceptively pointed out.

## 12.13. Tactics for enhancing communication and resolving conflict

River conservation typically leads to conflict because when water resources are allocated back to the environment, other users are denied water that could generate income. Multiple and competing values for water at a time when human populations are increasing, water resources are dwindling, water quality is deteriorating, and climate is changing is an inevitable result. In an ideal world, collaborative approaches that allow all stakeholders to express their concerns and feel satisfied with the resolution would predominate. There are many models proposed to promote this collaboration (e.g. Daniell 2011) and some examples where consensus has been achieved, leading to examples with varying success in river conservation (Chapter 13).

More commonly, conflicts arise. These are usually exacerbated by the centralized technocratic management of river basins and water resources coupled with minimal levels of interactive engagement with stakeholders. They arise because stakeholders have different values. The political process provides the forum for contesting these sets of values, and judgments are often made on the basis of short-term popularity rather than long-term benefit (Cullen 2006). Political conflicts are resolved by bargaining and negotiation, aiming to find a solution that will be supported by a coalition of interest groups; a marked contrast to the way that scientists resolve conflicting hypotheses in their research. And yet publication of science can fundamentally influence the political process by providing new information on the condition of resources.

Most conflicts have five key elements (Box 12.4). These elements commonly occur in environmental conflicts but are seldom clearly recognized by the players, hampering conflict resolution or problem identification. Further, some parties in many environmental conflicts are unaware of the tactics used by various interest groups to complicate the issues in an effort to maintain the status quo. River scientists, in particular, seem to be unaware of these tactics which range from repeated denial of the problem and the engagement of advocacy organizations to confuse issues further through to attempts to silence scientists who work in government agencies on the grounds that they should not be involved with policy (Cullen 2006).

Few aquatic scientists receive formal training in conflict resolution. We suggest that in addition to improving techniques of scientific communication with stakeholders in conservation debates, approaches to conflict resolution that promote joint benefits ("negotiation theory") should be taught to aquatic scientists entering political and management debates. These approaches would include adoption of problem-solving behaviour, minimizing "contentious behaviour" and understanding pro-social motivation where compromises are perceived as foregone gain rather than overall loss (e.g. Gelfland and Brett 2004). A few such courses in conservation conflict resolution exist (e.g. Society for Conservation Biology, Smithsonian National Zoological Park), although these appear to target terrestrial rather than aquatic scientists.

**Box 12.4**

## Conflict resolution in river conservation: Scientists and elements of environmental conflict

Multiple and competing demands for water in most rivers lead to conflict. Scientists can play an important role in helping resolve environmental conflicts. These include: identifying the problem's scope and implications, helping develop and evaluate strategies to solve the problem, modelling scenarios with and without a conservation intervention to help illustrate the consequences of particular actions, and monitoring the responses to conservation actions to inform Strategic Adaptive Management. Scientists also can contribute to getting an issue onto the political agenda, especially because they are likely to be among the first to recognize early warning signs of environmental decline (Likens 2010).

However, scientists are seldom trained in conflict resolution. They also must acknowledge that despite their important contributions listed above, conflict resolution is likely to be driven by value judgments and political consensus as a series of trade-offs. To appreciate this, we need to understand the five elements of an environmental conflict (Cullen 2006). These are:

1. Interests, relating to the personal benefit (e.g. financial reward, access to a resource) gained by an individual or group from a particular outcome;

2. Values, relating to personal attitudes to issues such as development versus conservation, social justice, human rights, etc.;

3. Data, including the conflicting parties' trust in the reliability of available information, its relevance to the particular issue and the way the data are used to address the conflict;

4. Structural issues, arising from the boundaries between organizations with different objectives (e.g. environmental protection agencies versus regional development agencies); and,

5. Risks, and the extent to which different parties in the conflict are willing to risk certain outcomes.

These five elements typify efforts to conserve and restore rivers. Their resolution is complicated because interests and values change over time, often in response to changes in economic situation or options for land use. Increasing population densities and predicted climate change are likely to lead to more intensive conflicts. River ecosystems are notoriously unpredictable and responses to interventions are seldom linear and consistent. This complicates the way that data can be used and may also influence judgements of risk. Finally, political will can be fickle and changeable in many countries, influencing the governance and structures of agencies and their emphases. Effective conservation and restoration of rivers rely on more than physical management; institutional management is just as important yet less widely appreciated (Chapter 13).

## 12.14. Conclusions

Until we better understand how to insert science into policy and planning in river conservation and restoration, much relevant, good science will continue to be overlooked or ignored. Sometimes, this will be intentional, entailing selective "science-picking" or "combat-science" between duelling hired consultants, and may damage the overall credibility of science, limiting its use in subsequent planning. Scientists concerned with river conservation and restoration need to become better trained and experienced at functioning at the interface between science, policy, planning and management. Our experiences in the California Delta and the Murray-Darling Basin provide some guidance on working at these interfaces where river conservation and restoration are major goals and objectives. Some lessons learned include: 1) developing, nurturing and sustaining communication links with policy makers and decision makers, 2) engaging directly in the planning process for major basin-wide initiatives, 3) identifying and supporting science champions for improving the role of science in river conservation, and 4) learning tactics for enhancing communication and resolving conflict. Successful river conservation and restoration will require more scientists willing to engage in planning, policy and management and better preparation for these scientists to work effectively in these allied fields critical for sustaining healthy river ecosystems.

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http://deltacouncil.ca.gov/science-program is the address for the Delta Science Program
http://deltacouncil.ca.gov/ is the web site for the Delta Stewardship Council

# LIST OF FIGURES