Open Research Online

Science–policy processes for transboundary water governance

Journal Item

For guidance on citations see FAQs.

oro.open.ac.uk

1   **Science-policy processes for transboundary water governance**
2

3   **Abstract**

4   In this policy perspective, we outline several conditions to support effective science-

5   policy interaction, with a particular emphasis on improving water governance in

6   transboundary basins. Key conditions include: 1) recognizing that science is a crucial but

7   bounded input into water resource decision making processes; 2) establishing conditions

8   for collaboration and shared commitment among actors; 3) understanding that social or

9   group learning processes linked to science-policy interaction are enhanced through

10   greater collaboration; 4) accepting that the collaborative production of knowledge about

11   hydrological issues and associated socio-economic change and institutional responses is

12   essential to build legitimate decision making processes; and 5) engaging boundary

13   organizations and informal networks of scientists, policy makers and civil society. We

14   elaborate on these conditions with a diverse set of international examples drawn from a

15   synthesis of our collective experiences in assessing the opportunities and constraints

16   (including the role of power relations) related to governance for water in transboundary

17   settings.

18

19   **Introduction**

20

21   Climate change will exacerbate already severe pressure on freshwater resources from

22   agriculture, industry and growing urban populations (Vörösmarty et al. 2000; Milly et al.

23   2008). Globally, significant changes in river flow have already been observed, while

24   projected changes in river flow under different climate and water withdrawal scenarios

25   point to significantly increased water stress in many jurisdictions (Palmer et al. 2008;

26   MacDonald 2010; Grafton et al. 2013).

27

28   Many of these changes are occurring in transboundary basins, which adds to the

29   complexity of problem analysis and identification of effective responses in these key

30   systems (Pahl-Wostl et al. 2013). About 45 percent of the Earth's land surface is covered

31   by 276 river basins shared by more than one country (De Stefano et al. 2012).

32   Transboundary basins at sub-national levels number in the thousands. Hundreds of

33   transboundary aquifers present even more challenging settings for governance (UNESCO

34   2009).

35

36   Barriers to effective water governance in transboundary settings are significant, and

37   include power imbalances, inadequate attention to rapidly changing biophysical

38   conditions and a growing array of social actors with a stake in decision making (Zeitoun

39   et al. 2013). Integrating different forms of knowledge – e.g., scientific, local, indigenous,

40   bureaucratic (Edelenbos et al. 2011) – has emerged as a key determinant of governance

41   success (Karl et al. 2007). Scientific knowledge – which for our purpose refers to

42   knowledge about social and natural phenomena that has been generated by people using

43   scientific methods – has long been considered authoritative. However, this is changing. It

44   is now widely accepted that scientific knowledge alone is not sufficient for dealing with

45   complex environmental issues (Lejano and Ingram 2009). At the same time, the gulf that

46   often exists between "decision makers" and scientists can be wide (Cash et al. 2003).

47   Recognition of this fact accounts for the enormous amount that is being written about

48   strategies to improve science-policy interaction (e.g., Roux et al. 2006; Karl et al. 2007;

49   Pielke 2007; Ascher et al. 2010; Kasperson and Berberian 2011).

50

51   Without diminishing the importance of other forms of knowledge, scientific knowledge

52   clearly remains central to addressing current and emerging water challenges. The barriers

53   to effective science-policy interaction for transboundary water governance are many and

54   can include military and security issues unrelated to water resources, pressures associated

55   with exploitation of resources of economic value (including water), imbalances of power

56   among and between decision makers and societies (see discussion below), and the self-

57   interest of upstream stakeholders over those downstream (Zeitoun et al. 2013; Zeitoun

58   and Warner 2006). Other political challenges to science-policy interactions for

59   transboundary water governance include allocating the high costs of organizing and

60   sharing data and information, disagreements about the accuracy and acceptability of

61   existing baseline data, and the use of data or information as a 'weapon' in directing blame

62   toward particular actors in a transboundary setting (Turton et al. 2003; Timmerman and

63   Langaas 2004; Grossman 2006).

64

65   In this brief perspective we identify five important conditions that – on the basis of our

66   combined expertise – can be identified as supportive of effective science-policy

67   interactions. The key conditions we emphasize include 1) recognizing that science is a

68   crucial but bounded aspect in water resource decision making processes; 2) establishing

69   initial conditions and shared commitment among actors; 3) understanding that social or

70   group learning processes linked to science-policy interaction are enhanced through

71   greater collaboration; 4) accepting that the collaborative production of knowledge about

72   hydrological and associated socio-economic change and institutional responses is

73   essential to build legitimate decision making processes; and 5) engaging boundary

74   organizations and supporting informal networks of scientists, policy makers and civil

75   society.

76

77   Our arguments emerge from our collective international experience and extensive

78   knowledge with science-policy processes in a wide range of transboundary basin settings.

79   During the past decade, we have worked on a range of natural and social science studies

80   in a variety of river basins, including most of the basins from which examples used in this

81   paper are drawn (see Table 1). To catalyze this synthesis of conditions, we met as a group

82   in 2012 for a symposium and workshop to refine our perspectives on the key conditions

83   presented here. We do not claim this list of conditions to be the final word. However,

84   they resonate with experiences in the literature in a host of environmental contexts. The

85   value they add comes from the way they are grounded in transboundary basin settings

86   where institutional conditions for governance and effective science-policy interactions are

87   highly complex.

88

89   **Challenges for effective science-policy interaction**

90

91   How science-policy processes can be enhanced to improve decisions about water (and

92   other resources) is a topic of much debate within the environmental science and policy

93   communities, and broad agreement exists around some key principles. For instance,

94   scientists are often encouraged to better communicate risk and uncertainty to non-

95   scientific audiences, and policy makers are urged to use the best available scientific

96   evidence (Guston 2004; Pielke 2007; Toderi et al. 2007). Overcoming disciplinary

97   isolation is also recognized as a priority (Kasperson and Berberian 2011).

98

99   A host of factors makes effective science-policy integration challenging in most water

100   decision making contexts, and especially in those involving more than one jurisdiction.

101   Institutional fragmentation across jurisdictions, unequal power among basin actors in

102   different jurisdictions, a potential for high levels of political conflict, and differences in a

103   culture of decision making contribute to 'wicked' (or 'super-wicked') problem contexts

104   (see Levin et al. 2012), and can undermine efforts to make the science-policy interface

105   work better. Here, we refer to wicked problems as those types of problems that are very

106   difficult (and perhaps impossible) to resolve because they are characterized by strong

107   interconnections and high degrees of uncertainty, incomplete information or

108   contradictory understandings, and value conflicts (see Rittel and Webber 1973).

109

110   Sutherland et al. (2013) recently synthesized twenty suggestions or 'tips' to improve the

111   integration of science in political decision making, with a focus on policy makers'

112   understanding of the imperfect nature of science. The list is helpful but ultimately

113   application of the ideas requires a social context in which scientists, policy makers and

114   others attempting to and engaged in governing can actually interact and deliberate. This

115   social context includes the diverse norms and values among the constellation of actors in

116   a water decision making process (e.g., industry groups, aboriginal communities) as well

117   as differences in power and authority among those individuals and organizations (see

118   below). These constraints have material consequences, and, as a result, uptake of

119   suggestions to improve integration of science in political decision making in real-world

120   settings will continue to be slow unless the social and institutional context for science-

121   policy interactions in transboundary water governance is accounted for and, where

122   inadequate, improved. The conditions we highlight in this perspective are a key part of

123   these improvements.

124

125   Doing and using science differently requires reflecting on what science is being used for;

126   understanding how results will be mobilized and by whom; overcoming fragmentation

127   among organizations and the knowledge used to inform decisions; recognizing the social

128   and political aspects of science-policy practices; and accounting for multiple framings of

129   problems and solutions (Roux et al. 2006; Lejano and Ingram 2009; Sutherland et al.

130   2013). Our experiences and the cases we draw upon for this paper demonstrate that *ad*

131   *hoc* approaches to science-policy integration are unlikely to succeed in complex settings

132   such as transboundary basins. The likelihood of success increases dramatically when

133   science-policy integration processes are institutionalized, in particular, when they are

134   incorporated into the culture, values and structures of transboundary water governance.

135   Multi-level networks catalyzed by a shared commitment to resolving transboundary water

136   problems have proven to be one effective way to help scientists, policy makers and

137   members of the communities they serve interact effectively (Sabatier et al. 2005).

138

139   The need to take into account the role of power and its manifestations in constraining,

140   facilitating and ultimately shaping science-policy interactions informs our perspective.

141   We suggest that scientists and policy makers must reflect more explicitly on how the

142   social relationships and institutional structures they co-create frame, constrain and enable

143   the agency of individuals and groups, as well as the way in which these relationships and

144   structure have material effects (e.g., influencing the uptake of ideas, how rules and

145   regulations are exercised). Agrawal and Ribot (1999) offer a practical way to consider

146   power, and draw attention to the power to create rules, make decisions, ensure

147   compliance with rules and decisions, and adjudicate resulting disputes. Moreover, within

148   these categories and among the various actors involved (e.g., state, NGOs, industry),

149   power may be visible, invisible and/or hidden (see Cornwall 2000). These various

150   dimensions of power and asymmetries of power they reflect strongly influence the five

151   conditions addressed here (Zeitoun and Warner 2006). Power asymmetries can at times

152   be extreme in transboundary settings (Zeitoun and Mirumachi 2008), as there is always

153   an upstream and a downstream party. Upstream parties usually have their way (see for

154   example Conca 2005) and natural dependencies can be exacerbated by differences in

155   economic and political clout (e.g., China's role in the Mekong region – see the discussion

156   below). Understanding who benefits and who loses is essential in any natural resource

157   management process (Raik et al. 2008), especially water governance (Ingram 1990).

158

159   **Conditions that support effective science-policy interaction in transboundary**

160   **settings**

161

162 In this section we elaborate on the five conditions identified previously. The discussion is

163 grounded in a diverse group of international transboundary settings where we have

164 collective experience (Table 1). We recognize that there is an underlying normative

165 assumption associated with the conditions we outline (e.g., that engaging with bridging

166 organizations or fostering learning will yield beneficial outcomes). The five conditions

167 we have identified here are not a panacea for what often seem to be intractable problems

168 in transboundary settings, or for problems with roots in state sovereignty concerns or

169 long-term historical conflicts among upstream and downstream water users. Rather, we

170 view these conditions as a starting point to address ongoing challenges when integrating

171 science and policy in a wide range of contexts, and as a basis to highlight the need to

172 better understand how to create a social context for science-policy interactions. This need

173 exists in numerous environmental contexts. Hence, the transboundary frame we use here

174 provides a concrete setting to explore these issues.

175

176 *Science as one input to policy making*

177

178 Perceptions of science-policy processes as linear ignore the messy reality in which

179 decisions are actually made (McNie 2007; Vogel et al. 2007). A wide range of actors is

180 now involved in making decisions about water (Pahl-Wostl and Kranz 2010), and the

181 position and role of scientists in decision processes has changed. This trend is part of a

182 broader shift in society towards greater citizen skepticism about science combined with

183 the democratization of knowledge (Pielke 2007; Lejano and Ingram 2009). For scientists,

184 these trends demand a greater willingness to work in settings where other players are

185   helping to shape the research agenda. Scientists who work in these settings need support

186   from governments and universities (e.g., access to databases and literature behind

187   paywalls, flexibility to take more time to do research that involves communities), and

188   they must be open as well to communicating their science better to a diversity of

189   audiences. Rewards, incentives and requirements for scientists to participate in more open,

190   collaborative and learning-centered processes are also needed (Ison et al. 2007; Wolfe et

191   al. 2007). In Canada's Mackenzie Basin, for example, the Aurora Research Institute

192   (which assigns permits to conduct scientific research in the Northwest Territories portion

193   of the basin) has developed templates for scientists (natural and social) to use when

194   communicating their research to communities. Implicit in this shift to share and

195   communicate knowledge more effectively is a concern that scientific knowledge is not

196   'elevated' above or valued to the detriment of traditional knowledge and traditional

197   knowledge holders which has (and often continues to be) the case (Nadasdy 1999).

198

199   The importance of accepting that science is only one input into policy making is

200   particularly evident in transboundary basins. Governments are – and likely always will

201   remain – critical actors in transboundary settings because of their political authority and

202   jurisdiction. However, increasingly it is recognized that governance in transboundary

203   basins involves diverse government and non-government actors, and that a global shift in

204   views about roles and responsibilities of the state is underway (Bruch et al. 2005; Cosens

205   2010; Akamani and Wilson 2011). Governments are being expected to transition from

206   being primarily holders of expertise and the main decision making power to also be

207   facilitators and knowledge brokers (Pielke 2007; Kasperspon and Berberian 2011).

208   However, there can be significant differences between participatory transboundary water

209   governance and actually crafting inclusive and effective science-policy interactions that

210   value a range of knowledge sources and types (see below).

211

212   While not without its challenges, increased participation by a greater array of non-

213   government actors in transboundary settings can lead to greater legitimacy, more

214   effective and equitable allocation of resources, a better ratio of costs to benefits, and

215   improved access to a diversity of knowledge and expertise (Raadgever et al. 2008), as

216   well as broader acceptance and implementation success. For example, several ecological

217   monitoring programs linking scientific and traditional knowledge have been developed

218   for the Mackenzie River Basin, an enormous internal basin shared by five sub-national

219   jurisdictions within Canada. These programs create space for local and traditional

220   knowledge holders, along with scientists, to identify monitoring priorities and to conduct

221   monitoring that provides information about local ecosystem conditions considered

222   important to local communities. A recent example from this setting is the multi-actor

223   Slave River and Delta Partnership. This partnership was created to facilitate community-

224   based monitoring in response to the concerns of aboriginal people and local residents

225   regarding ecosystem health and to provide a mechanisms to increase the 'voice' of

226   communities in decision making (see Box 1).

227

228   Greater participation does certainly not always lead to acceptance and improved

229   implementation if other conditions for success are not in place. For example, Mirumachi

230   and Van Wyk (2010) have pointed to the risks associated with an emphasis on

231 cooperation for inclusive, participatory water governance in South Africa and the

232 Orange-Senqu River Basin. They suggest that processes of devolving decision-making

233 authority and including non-state actors may simply reproduce power asymmetries,

234 preventing meaningful empowerment and inclusion and ultimately, more equitable water

235 governance. In such cases, participatory processes may not adequately address the

236 underlying conflicts that constrain implementation, despite institutional frameworks set

237 up to promote better water governance. Experiences in managing the transboundary

238 waters of the Orange-Senqu River in particular highlight the complex political and

239 economic contexts in which water supply and demand become contested. For example,

240 the Orange-Senqu Water Information System has been established to collate, share and

241 disseminate reports and data for public use. However, the inter-state political

242 negotiations over water allocation are bound by considerations of existing water use,

243 highlighting that data sharing in and of itself does not address perceived inequity (Keller

244 2012). Consequently, science needs to be understood as just one input in decisions

245 about transboundary water governance and the ways in which unequal power can shape

246 and constrain access to decision-making.

247

248 *Establish conditions for collaboration and shared commitment early on*

249

250 Governance of complex environmental problems (such as those experienced in many

251 transboundary basins) requires joint activity, including joint-fact-finding, from which

252 trust-building emerges at the onset of science-policy collaborations. Building

253 relationships to overcome perceptions about the different logics of science (e.g., primarily

254 facts, neutrality) and policy (e.g., primarily values, interests) takes time (Huitema and

255 Turnhout 2009), with few tangible outcomes in the initial stages (Collins and Ison 2010).

256 However, investing time up front in joint problem-framing, and engaging policy makers

257 and other actors (civil society groups, industry, etc.) in the knowledge production process

258 rather than treating them as passive end users helps to ensure that high initial transaction

259 costs will yield dividends over the longer term. Early investments of time and resources

260 are needed to create common understanding of key questions and the broader political

261 and socio-cultural contexts that frame decisions about water. Also important are regular

262 cycles of carefully designed workshops and stakeholder meetings, getting key people

263 engaged for the duration of the process, and ensuring that any collective achievements are

264 institutionalized through practices, agreements or legislation (Karl et al. 2007).

265

266 Recent experiences in Australia's Murray-Darling Basin (MDB) starkly reveal the

267 importance of both initial conditions and shared commitment. The basin jurisdictions,

268 including the Commonwealth government, demonstrated a strong commitment to jointly

269 address the basin's water allocation problems including a significant financial investment

270 of $A10 billion. Since 2007 a new MDB plan has emerged from an often fractious

271 process. New institutions have been conceived and implemented such as 'environmental

272 flows', 'environmental water' and the 'office of environmental water holder'. However,

273 Wallis and Ison (2011) have argued that the structural constrains imposed on the Murray-

274 Darling Basin Authority by the federal *Water Act 2007*, along with the deeply rooted

275 competing interests among and within states, effectively guarantees that ongoing

276 governance of the basin will be contested, and during implementation may be prone to

277 systemic failure.

278

279 In the Danube and Orange-Senqu river basins, organizations such as the International

280 Commission for the Protection of the Danube River and Orange-Senqu River

281 Commission, respectively, encourage data sharing and coordination among multiple

282 parties (but not without its problems, as explained below on the latter basin). In the

283 Mackenzie River Basin, the Mackenzie River Basin Board's Traditional Knowledge and

284 Strengthening Partnership Steering Committee is identifying best practices to incorporate

285 local, indigenous knowledge in water management practices based on reflection and

286 ongoing initiatives. Although capacity challenges persist, efforts to share data, develop

287 common objectives and institutionalize processes of knowledge exchange can contribute

288 to improved water governance in these contexts.

289

290 High political stakes, including a potential for conflict and often unequal power relations,

291 are common in transboundary settings such as the ones considered in Table 1. This makes

292 the challenge to establish inclusive initial conditions for science-policy interactions all the

293 more crucial (Paisley and Henshaw 2013). Actors on different sides of political

294 boundaries may have competing interests, and strong reasons to avoid scientific input;

295 they may only seek scientific input to support particular bargaining positions. In the

296 absence of a supportive institutional framework, legitimate decision making processes

297 and shared framing of science can be particularly hard to achieve in transboundary basins

298 (Pahl-Wostl and Kranz 2010).

299

300 Political commitment to cooperation, demonstrated tangibly through, for example,

301 transfers of decision authority and resources and non-state actors involved in knowledge

302 production processes, is also vital. This level of commitment is difficult to achieve in

303 transboundary basins because national economic development objectives can trump the

304 precaution required to address scientifically and socially complex issues (Lebel et al.

305 2005). For example, in the case of rapid hydropower development in the Mekong River

306 basin, national interests of basin states have undermined the ability of the Mekong River

307 Commission (convened by Laos, Thailand, Cambodia and Vietnam) to facilitate joint

308 problem framing (Hirsch et al. 2006). China is not part of the Commission, but rather an

309 observer, raising questions about the extent to which the river basin organisation can

310 address the issue of hydropower development, some of which is going on in upstream

311 Chinese territory. Moreover, hydropower development is operationalized by both the

312 private sector and government in the form of public–private partnerships and build-

313 operate-transfer schemes (Middleton et al. 2014). Understanding how national economic

314 development objectives are forged by certain stakeholders is important. Power

315 asymmetries and obstacles to commitment to cooperation exist not just at the

316 international transboundary level but also within the individual basin states themselves.

317

318   Space for alternative development scenarios is reduced when national governments

319 prioritize large hydro-electric projects to the exclusion of other possible avenues of

320 economic development. This process is supported by macro-economic studies and cost-

321 benefit analysis that suggest significant economic benefits from hydropower (see

322 Flyvberg 2005). Alternative considerations of non-market values and the lived

323   experiences of hydropower development do not inform such studies and approaches

324   (Mirumachi and Torriti 2012). As a result, reports by civil society groups pointing to less

325   desirable impacts of dams based on alternative metrics commonly count less in the

326   decision making process.

327

328   *Learning to learn through collaboration*

329

330   Shared understanding of problems and solutions is essential for dealing with complex

331   environmental problems. Social learning is one way this can be achieved, and refers to

332   changes in understanding that go "beyond the individual to become situated within wider

333   social units or communities of practice through social interactions between actors within

334   social networks" (Reed et al. 2010). Social learning processes may seem outside the remit

335   of scientists, especially when science-policy linkages are viewed as linear. However,

336   social learning processes can help to link policy makers, scientists and other key actors

337   (members of the public, non-governmental organizations, aboriginal groups) through

338   their emphasis on communication, deliberation and group interaction (e.g., meetings,

339   workshops, study tours and visits) (Scott et al. 2012). This can help stakeholders to deal

340   with significant uncertainty and complexity, and if social learning processes are well

341   designed (see Bos et al. 2013), they can help surface the relationships of power that must

342   be accounted for if meaningful actions are to be taken (Armitage et al. 2009). In the

343   Murray-Darling Basin, salinity management programs at the regional level in New South

344   Wales incorporated context-specific learning, community participation and multiple types

345   of knowledge. These programs resulted in community and government acceptance of

346 salinity-control measures and greater awareness of salinity hazards. Unfortunately,

347 however, governance has shifted from a community-based to state-dominated model

348 predicated on centralization that has made institutionalizing social learning and

349 transformative change difficult (Wallis et al. 2013) and introduced social inequities due to

350 top-down innovation approaches for irrigation renewal (Wallis et al. 2015).

351

352 Learning to learn together ultimately requires that scientists, policy makers and a wide

353 range of non-state actors are open to hybrid roles and a new 'social contract' (Lubchenco

354 1998; Palmer 2012). In transboundary water governance settings, barriers to social

355 learning can exist that go beyond simply the presence of political boundaries. A desire on

356 the part of actors in different jurisdictions to learn together may be insufficient in the face

357 of institutional rigidity often created by less flexible treaties and compacts. The Colorado

358 River offers an instructive case in the long-term challenge of moving towards a more

359 learning-oriented and collaborative approach.

360

361 The history of river management in the Colorado basin is one of fragmentation with

362 competition among a broad array of water interests (agriculture, ranching, municipal),

363 including conflict between the United States federal government and various states

364 (Getches 1997). However, an incremental approach to more inclusive governance of the

365 Colorado River basin has emerged over several decades with greater attention to bi-

366 national cooperation between the United States and Mexico (Getches 2003; Gerlak et al.

367 2013). Most recently, the Colorado Basin Study – a multi-agency and multi-government

368 effort – offers an example of how a broad array of non-state and state actors, along with

369   diverse scientific expertise, can be brought together to redefine management problems,

370   and to incorporate science into decision making about current and projected challenges

371   (United States Department of the Interior 2012). Issues in the Colorado River Basin have

372   not been resolved and climatic changes in the region will exacerbate challenges requiring

373   ongoing attention to building knowledge collaboratively. Still, in comparison to the prior

374   history of science-policy interactions and governance in the basin, significant steps

375   forward are evident especially in the Colorado River Delta, and in the lower part of the

376   Basin. For example, in recent years, a diverse set of government officials, scientists and

377   NGOs have been engaged in experimental management practices, as exemplified by the

378   2014 pulse flow event which brought water to the parched Colorado River Delta, to

379   collaboratively learn about river restoration (Howard 2014; Gerlak 2015).

380

381   *Produce and use knowledge of all types*

382

383   As noted in the introduction, contemporary water governance must draw on knowledge in

384   its many different forms (scientific, local, indigenous, bureaucratic). This knowledge is

385   held, formulated and communicated by a variety of actors inside and outside government,

386   at all scales (Lejano and Ingram 2009). Integrating different kinds of knowledge in water

387   decision making can be extremely challenging because of differing, potentially

388   contradictory and sometimes incompatible ways of knowing (e.g., between scientific and

389   traditional knowledge systems). Openness to the use of multiple types of knowledge is

390   important for legitimate decision making processes (Taylor and de Loë 2012), as is a

391   commitment to processes of 'knowledge co-production' in which a plurality of

392   knowledge sources and types is brought together to define and resolve problems

393   (Armitage et al. 2011). Processes of knowledge co-production are not intended to resolve

394   situations where knowledge and understanding about water conditions are

395   incommensurate. For example, there may be instances where fundamental disagreements

396   remain on sources of water contamination, as is happening in Mackenzie Basin with

397   regard to oil sands contamination in downstream deltas (Timoney and Lee 2009; Hall et

398   al. 2012). However, knowledge co-production processes do help participants to view

399   knowledge not simply as a product, but instead as an outcome of relationships in which

400   different information, knowledge and values are recognized as being tightly connected

401   (Edelenbos et al. 2011). In transboundary water governance settings, these forms of

402   interaction have important implications for how science and scientists are engaged with a

403   broader range of actors and in ways that challenge notions of certainty about system

404   conditions.

405

406   In the Mackenzie Basin, for example, scientists and traditional knowledge holders (those

407   individuals with a long-term engagement on the land as harvesters and trappers) are

408   working together in new ways through the Peace-Athabasca Delta Ecological Monitoring

409   Program, and specifically, by collaborating on wildlife and environmental surveys.

410   Initially, there was some apprehension among scientists and traditional knowledge

411   holders about working together but over time they have come to value collaborating to

412   share knowledge, as has been our experience in similar contexts (Wolfe et al. 2007). It is

413   often difficult for people more comfortable with technical information and 'hard facts' to

414   engage someone whose knowledge emerges from ongoing interactions with the land, and

415   who might communicate that knowledge through stories, perceptions of change and a

416   tendency to situate their knowledge in a broader discourse about values (Wolfe et al.,

417   2007; Armitage et al. 2011; Taylor and de Loë 2012). Ultimately, these changes in

418   relationships and focus on knowledge require a tacit recognition of differences in power,

419   willingness on the part of the individuals involved to relinquish in some cases the

420   positions of power they do hold, and a commitment to trust building (Armitage et al.

421   2009).

422

423   The co-production of knowledge can be especially important in transboundary water

424   governance settings where objectives, targets and goals often must be negotiated among

425   actors who lack the power to enforce their views on each other. Monitoring in a

426   transboundary water governance context is one vehicle for knowledge co-production

427   because it also situates assessment, reflection, and learning in specific empirical contexts.

428   Along the Danube River, information sharing, exchange, and harmonization have been

429   primary objectives of the International Commission for the Protection of the Danube

430   River (ICPDR) from its inception in the early-1990s (ICPDR 2007). Such efforts feed

431   into the Danube River Basin Management Plan, which outlines concrete measures to be

432   implemented by the year 2015 to improve environmental conditions (Weller and Popovici

433   2011). Demonstrating improvements in ecological conditions and coordinating among the

434   diverse institutions involved in managing the Danube prove challenging (Gerlak 2004).

435   However, the information collected provides: (i) a solid foundation of agreed-upon data

436   which simplifies the process of developing management plans, and (ii) consistent

437   reporting on achievements and remaining challenges in restoring water quality

438   throughout the basin to better guide decision makers on policy measures (Schmeier 2014).

439

440   *Engage boundary organizations and informal networks*

441

442   Boundary organizations work at the interface of governmental and non-governmental

443   spheres, and typically are the formal bodies that mediate interactions (e.g., about values,

444   purposes, strategies) among social actors (Guston 2004; Crona and Parker 2012).

445   Evidence from different environmental policy and governance settings indicates that

446   these organizations can serve as clearing houses for information, foster conflict resolution,

447   and, where supported by legislation, build the legitimacy and credibility needed to

448   encourage behavioral change (Cash et al. 2003; Huitema and Turnhout 2009; Crona and

449   Parker 2012). To achieve these potential benefits, however, boundary organizations

450   require cultivation, experience and involvement from stakeholders at higher and lower

451   levels of governance. Where boundary organizations do not exist, or where they are

452   ineffective, informal networks of scientists, policy makers, and community members can

453   sometimes fill gaps (Huitema and Meijerink 2009). In these settings informal networks

454   may emerge that can institutionalize science-policy processes longer-term. Informal

455   networks can utilize scientific information and local knowledge to help work around

456   political resistance, entrenched approaches, or attachments to the old ways of doing

457   things. In turn, such networks can catalyze demonstration projects at smaller scales (e.g.,

458   demonstration projects or sites within a transboundary context), and subsequently

459   communicate lessons learned to a broader policy context (Roux et al. 2006).

460

461   Boundary organizations and informal networks can play especially important roles in

462   linking scientists, policy makers, communities and other actors across jurisdictions or in

463   transboundary basins (Huitema and Meijerink 2009). This is the case in the Canadian

464   portion of the St. John River, a transboundary river shared by Canada and the United

465   States. Here, an informal network of watershed organizations emerged, despite the failure

466   by the provincial government to implement water protection recommendations from its

467   own watershed classification strategy (Baird et al. 2014). This network advocated for the

468   implementation of key provisions of the strategy, and had a scope and influence that

469   ultimately had the government re-engage with the issue and with a range of water actors.

470   One of the watershed organizations in the network requested the Provincial Ombudsman

471   to investigate the process around the strategy. The investigation highlighted a long term

472   and ongoing lack of communication both within government agencies and with watershed

473   stakeholders regarding the status of the strategy and opportunities or alternatives to move

474   forward (Office of the Ombudsman, 2014). Significant pressure is thus being directed on

475   the new government to take corrective actions, while watershed organizations and other

476   actors continue to forge important linkages about freshwater concerns in the basin.

477

478   More formal, government-led river basin organizations such as the Mekong River

479   Commission or the Orange-Senqu River Commission also can serve as a type of

480   boundary organization. These organizations can have specific responsibilities to link

481   scientists, donor agencies, policy makers and communities vertically and horizontally,

482   and as a result, they can function as key nodes in the development of more tightly-

483   coupled networks of scientists, policy makers and civil society actors (e.g., industry,

484   community organizations) seeking to be engaged in decision making. In the Orange-

485   Senqu River Basin, the Orange-Senqu River Commission facilitates information

486   gathering and sharing within the four basin nation states. However, it cannot fully resolve

487   the differences in scientific and technical capacity between basin states which result in

488   challenges providing timely and accurate data. The Mekong River Commission

489   encourages data and information exchange regarding hydrology, biodiversity and

490   fisheries in the form of State of the Basin Reports. It builds technical capacity (as well as

491   institutional and social capacity), through its Flood Management and Mitigation Program

492   and Initiative on Sustainable Hydropower, which supports adaptation to future stressors

493   (Heikkila et al. 2013). However, like the Orange-Senqu, limited capacity in some states

494   is a challenge for data acquisition. Furthermore, boundary organizations must contend

495   with issues of data sharing with non-member states, as in the case of the Mekong River

496   Commission and its interaction with upstream China. The Mekong River Commission

497   has its strengths and weaknesses depending on different programmatic areas (Heikkila et

498   al. 2013), and identifying areas with strong or weak organizational capacity will be

499   important.

500

501   **Conclusion**

502

503   Blueprints for effective science-policy processes in transboundary water governance

504   settings do not exist because, as in water governance generally, problems and solutions

505   are complex and context specific (Ingram 2013). Nonetheless, it is possible to identify

506   conditions that are likely to increase the chances of success based on international

507 experiences. We have done so here using transboundary water governance examples but

508 recognize the value of engaging with a wide range of practitioners and scholars in diverse

509 settings to further reflect upon and build an evidence base of the conditions for effective

510 science-policy processes.

511

512 The five conditions considered in this perspective reflect the importance of networks of

513 science and policy actors, as well as a range of non-state actors engaging in new forms of

514 collaboration. Engaging the right people as actors in these processes through experience

515 and interdisciplinary training is necessary. Identifying and publicizing successful cases

516 (in developed and developing countries) of science-policy interactions will help, as will

517 recalibration of traditional measures of scientific success to emphasize processes that are

518 credible, legitimate and salient.

519

520 Recent experiences in the vast transboundary Mackenzie Basin in Canada reflect many of

521 the conditions and lessons outlined in this policy perspective (see Box 1), with the cases

522 in Table 1 offering supporting examples. As previously noted, science-policy interactions

523 often reflect unequal relations of power between nation states (or sub-national

524 jurisdictions, such as is the case in the Mackenzie Basin). In some contexts, deliberative

525 approaches in political arenas can create new spaces for actors to engage on difficult

526 issues and build trust (Dore 2014). However, efforts to further science-policy interactions

527 in the Mackenzie Basin are complicated by more than jurisdictional differences in power.

528 There are vested industry interests associated with oil sands production and pressure to

529 engage with new technologies (e.g., fracking) that can subvert local deliberative

530   processes, transboundary governance and multi-scale efforts to institutionalize science-

531   policy interactions. These circumstances do not imply that efforts to foster science-policy

532   interactions will fail, and there are in fact many innovative efforts taking place in the

533   Mackenzie Basin (See Box 1). However, they do make the task all that more challenging.

534

535   Given the expanding envelope of variability within which multi-jurisdictional decisions

536   about water must be made, failure to 'invent' new, conducive, institutions and to

537   institutionalize conditions for better decision making presents significant risks to society

538   and ecosystems. Moving forward, therefore, systematic and comparative assessment is

539   required to identify the full range of conditions for science-policy success (and those

540   conditions that create barriers) across a large sample of transboundary river basins in a

541   diversity of jurisdictional settings (e.g., international, sub-national). Even with the

542   application of the five conditions we have identified, some failures in bridging science

543   and policy are inevitable. An ongoing commitment to foster collaborative knowledge

544   networks is required to deal with change in transboundary settings. However, as the

545   examples in this perspective have shown, focusing on strategies and conditions to

546   facilitate science-policy interactions is a pragmatic entrée to resolve water decision

547   challenges in spite of the broader political forces (i.e., imbalances or asymmetries of

548   power, upstream-downstream conflicts) that too often undermine the cooperation and

549   integration crucial for sustainability.

550

551   **Acknowledgements**

559

560

561 **References**

562

563 Agrawal, A., and J. Ribot. 1999. Accountability in decentralization: A framework with

564 South Asian and West African cases. *Journal of Developing Areas* 33:473–502.

565

566 Akamani, K., and P.I. Wilson. 2011. Toward the adaptive governance of transboundary

567 water resources. *Conservation Letters* 4: 409-416.

568

569 Armitage, D., F. Berkes, A. Dale, E. Kocho-Schellenberg, and E. Patton. 2011. Co-

570 management and the co-production of knowledge: Learning to adapt in Canada's

571 Arctic. *Global Environmental Change* 21: 995–1004.

572

573 Armitage, D., R. Plummer, F. Berkes, R. Arthur, A. Charles, I. Davidson-Hunt, A.

574 Diduck, N. Doubleday, et al. 2009. Adaptive co-management for social-ecological

575 complexity. *Frontiers in Ecology and the Environment* 7: 95-102.

576

577 Ascher, W., T. Steelman, and R. Healy. 2010. *Knowledge and environmental policy: Re-*

578 *imagining the boundaries of science and politics*. Cambridge: MIT Press.

579

580 Baird, J., R. Plummer, S. Morris, S. Mitchell, and K. Rathwell. 2014. Enhancing source

581 water protection and watershed management: Lessons from the case of the New

582 Brunswick Water Classification Initiative. *Canadian Water Resources Journal* 39: 49-62.

583

584 Bos, J.J., R.R. Brown, and M.A. Farrelly. 2013. A design framework for enabling social

585 learning situations. *Global Environmental Change* 23: 328-412.

586

587 Bruch, C., L. Janksy, M. Nakayama, K. Salewicz, and A. Cassar. 2005. From theory to

588 practice: An overview of approaches to involving the public in international watershed

589 management. In *Public Participation in the Governance of International Freshwater*

590 *Resources*, ed. C. Bruch, L. Jansky, M. Nakayama, and K. Salewicz, 3-18. New York:

591 United Nations University Press.

592

593 Cash, D., W. Clark, F. Alcock, N. Dickson, N. Eckley, D. Guston, J. Jäger, and R.

594 Mitchell. 2003. Knowledge systems for sustainable development. *PNAS* 100: 8086-8091.

595

596 Collins, B., and R. Ison. 2010. Trusting emergence: Some experiences of learning about

597 integrated catchment science with the Environment Agency of England and Wales. *Water*

598 *Resource Management* 24: 669-668.

599

600 Conca, K. 2005. *Governing water: Contentious transnational politics and global*

601 *institution building*. Cambridge MA: MIT Press.

602

603 Cornwall, A. 2002. Making spaces, changing places: Situating participation in

604 development. IDS Working Paper 170. Brighton, UK: Institute of Development Studies.

605

606   Cosens, B. 2010. Transboundary river governance in the face of uncertainty: Resilience

607   theory and the Columbia River Treaty. *Journal of Land, Resources and Environmental*

608   *Law* 30: 229-265.

609

610   Crona, B.I., and J.N. Parker. 2012. Learning in support of governance: Theories, methods,

611   and a framework to assess how bridging organizations contribute to adaptive resource

612   governance. *Ecology and Society* 17: 32. doi.org/10.5751/ES-04534-170132

613
614   De Stefano, L., Duncan, J., Dinar, S., Stahl, K., Strzepek, K.M. and Wolf, A.T. 2012.

615   Climate change and the institutional resilience of international river basins. *Journal*

616   *of Peace Research* 49 1: 193–209.

617

618   Dore, J. 2014. An agenda for deliberative water governance arenas in the Mekong. *Water*

619   *Policy* 16: 194-214.

620

621   Earle, A., D. Malzbender, A. Turton, and E. Mazungu. 2005. A preliminary basin profile

622   of the Orange/Senqu River: AWIRU, University of Pretoria, South Africa.

623

624   Edelenbos, J., A. Van Buuren, and N. van Schie. 2011. Co-producing knowledge: Joint

625   knowledge production between experts, bureaucrats and stakeholders in Dutch water

626   management projects. *Environmental Science and Policy* 14: 675-684.

627   Flyvbjerg, B. 2005. Machiavellian megaprojects. *Antipode* 37 1 :18‐22.

628

629   Gerlak, A.K. 2004. Strengthening river basin institutions: The Global Environmental

630   Facility and the Danube River Basin. *Water Resources Research* 40, W08S08.

631   doi:10.1029/2003WR002936.

632

633   Gerlak, A.K. 2015. Resistance and reform: Transboundary water governance in the

634   Colorado River Delta. *Review of Policy Research*. 32(1): 100-123.

635

636   Gerlak, A.K., F. Zamora-Arroyo, and H. Kahler. 2013. A delta in repair: Restoration,

637   binational cooperation and the future of the Colorado River Delta. *Environment: Science*

638   *and Policy for Sustainable Development* 55: 29-40.

639

640   Getches, D.H. 1997. Colorado River governance: Sharing federal authority as an

641   incentive to create a new institution. *University of Colorado Law Review* 68: 573-658.

642

643   Getches, D.H. 2003. Water management in the United States and the fate of the Colorado

644   River Delta in Mexico. *United States-Mexico Law Journal* 11: 107-113.

645

646   Government of Canada. 2010. Northwest Territories environmental audit. Published

647   under the authority of the Minister of Indian Affairs and Northern Development and

648   Federal Interlocutor for Métis and Non-Status Indians, Ottawa, Ontario.

649

650 Grafton, R.Q., J. Pittock, R. Davis, J. Williams, G. Fu, M. Warburton, B. Udall, R.

651 McKenzie, et al. 2013. Global insights into water resources, climate change and

652 governance. *Nature Climate Change* 3: 315-321.

653

654 Grossmann, M. 2006. Cooperation on Africa's international water bodies: information

655 needs and the role of information-sharing. In *Transboundary Water Management in*

656 *Africa: Challenges for Development Cooperation*, ed. W. Scheumann, S. Neubert, and V.

657 Böge, 173-235. Bonn: German Development Institute.

658

659 Guston, D.H. 2004. Forget politicizing science. Let's democratize science! *Issues in*

660 *Science and Technology* 21: 25-28.

661

662 Hall R.I., Wolfe B.B., Wiklund J.A., Edwards T.W.D., Farwell A.J., et al. 2012. Has

663 Alberta Oil Sands Development Altered Delivery of Polycyclic Aromatic Compounds to

664 the Peace-Athabasca Delta? PLoS ONE 7(9): e46089. doi:10.1371/journal.pone.0046089

665

666 Heikkila, T., A.K. Gerlak, A. Bell, and S. Schmeier. 2013. Adaptation in a transboundary

667 river basin: Linking stressors and adaptive capacity within the Mekong River

668 Commission. *Environmental Science and Policy* 25: 73-82.

669

670 Hirsch, P., K.M. Jensen, B. Boer, N. Carrard, S. FitzGerald, and R. Lyster. 2006.

671 National interests and transboundary water governance in the Mekong. Danish

672 International Development Assistance and the University of Sydney. Sydney: Australian

673   Mekong Resource Centre.

674

675   Howard, B.C. 2014. Historic "pulse flow" brings water to parched Colorado River Delta.

676   *National Geographic* (March 22). Retrieved 9 September, 2014, from

677   http://news.nationalgeographic.com/news/2014/03/140322-colorado-river-delta-pulse-

678   flow-morelos-dam-minute-319-water/

679

680   Huisman, P., J. Jong, and L. Wieriks. 2000. Transboundary cooperation in shared river

681   basins: Experiences from the Rhine, Meuse and North Sea. *Water Policy* 2: 83-97.

682

683   Huitema, D., and E. Turnhout. 2009. Working on the boundary between science and

684   policy: A discursive analysis of boundary work at the Netherlands Environment Agency.

685   *Environmental Politics* 18: 576-594.

686

687   Huitema, D., and S. Meijerink (eds.) 2009. *Water policy entrepreneurs: A research*

688   *companion to water transitions around the globe*. Cheltenham: Edward Elgar.

689

690   ICPDR (International Commission for the Protection of the Danube River). 2007. 15

691   years of managing the Danube River 1991-2006. UNDP/GEF Danube Regional Project,

692   Vienna, Austria.

693

694   Ingram, H. 1990. *Water politics: continuity and change.* Albuquerque: University of

695   New Mexico Press.

696

697   Ingram, H. 2013. No universal remedies: Design for context. *Water International* 38: 6-

698   11.

699

700   Ison, R., and P. Wallis. 2011. Planning as performance: The Murray–Darling Basin plan.

701   In *Basin Futures: Water Reform in the Murray–Darling Basin*, ed. D. Connell, Q.

702   Grafton, 399-411. Canberra: ANU ePress.

703

704   Ison, R., N. Röling, and D. Watson. 2007. Challenges to science and society in the

705   sustainable management and use of water: Investigating the role of social learning.

706   *Environmental Science and Policy* 10: 499-511.

707

708   Karl, H.A., L.E. Susskind, and K.H. Wallace. 2007. A dialogue, not a diatribe: Effective

709   integration of science and policy through joint fact finding. *Environment* 49: 20-34.

710

711   Kasperson, R.E., and M. Berberian (ed.). 2011. *Integrating science and policy:*

712   *Vulnerability and resilience in global environmental change*. London: Earthscan.

713

714   Keller, E.J.K. 2012. Critiquing cooperation: Transboundary water governance and

715   adaptive capacity in the Orange–Senqu Basin. *Journal of Contemporary Water Research*

716   *and Education*. 149(1): 41–55.

717   Lebel, L., Garden, P. and M. Imamura. 2005. Politics of scale, position, and place in the

718   governance of water resources in the Mekong region. Ecology and Society 10(2): 18.

719   [online] URL: http://www.ecologyandsociety.org/vol10/iss2/art18/

720

721   Lejano, R., and H. Ingram. 2009. Collaborative networks and new ways of knowing.

722   *Environmental Science and Policy* 12: 653-662.

723

724   Levin, K., B. Cashore, S. Bernstein, and G. Auld. 2012. Overcoming the tragedy of super

725   wicked problems: Constraining our future selves to ameliorate global climate change.

726   *Policy Sciences* 45:123–152.

727

728   Lubchenco, J. 1998. Entering the century of the environment: A new social contract for

729   science. *Science* 279: 491-496.

730

731   MacDonald, G.M. 2010. Water, climate change, and sustainability in the southwest.

732   *PNAS* 107: 21256-21262.

733

734   Mackenzie River Basin Board (MRBB). 2003. State of the aquatic ecosystem report.

735   Mackenzie River Basin Board, Fort Smith, Northwest Territories, Canada.

736

737   McNie, E.C. 2007. Reconciling the supply of scientific information with user demands:

738   an analysis of the problem and review of the literature. *Environmental Science and Policy*

739   10: 17-38.

740

741   Mekong River Commission (MRC). 2010. State of the basin report 2010. Mekong River

742   Commission, Vientiane, Lao PDR.

743

744   Middleton, C., Matthews, N. and Mirumachi, N. 2014. Whose risky business? Public–

745   Private Partnerships (PPP), Build-Operate-Transfer (BOT) and large hydropower dams in

746   the Mekong Region. In *Hydropower development in the Mekong Region: political, socio-*

747   *economic and environmental perspectives,* eds. N. Matthews and K. Geheb, 127-152.

748   Routledge: London.

749

750   Milly, P.C.D., J. Betancourt, M. Falkenmark, D. Lettenmaier, and R.J. Stouffer. 2008.

751   Stationarity is dead: Whither water management? *Science* 319: 573-574.

752

753   Mirumachi, N., and E. Van Wyk. 2010. Cooperation at different scales: challenges for

754   local and international water resource governance in South Africa. *The Geographic*

755   *Journal* 176: 25-38.

756

757   Mirumachi, N., and J. Torriti. 2012. The use of public participation and economic

758   appraisal for public involvement in large-scale hydropower projects: Case study of the

759   Nam Theun 2 Hydropower Project. *Energy Policy* 47: 125-132.

760

761   Murray Darling Basin Commission (MDBC). 2003. Murray-Darling Basin Water

762   Resources Fact Sheet. Murray Darling Basin Commission, Canberra.

763

764   Nadasdy, P. 1999. The politics of TEK: Power and "integration" of knowledge. *Arctic*

765   *Anthropology* 36: 1-18.

766

767   Orange-Senqu River Commission (ORASECOM). 2010. Joint baseline survey-1:

768   Baseline water resources quality state of the Orange-Senqu River System in 2010.

769   ORASECOM, Centurion, South Africa.

770

771   Pahl-Wostl, C., and N. Kranz. 2010. Water governance in times of change.

772   *Environmental Science and Policy* 13: 567-570.

773

774   Pahl-Wostl, C., M. Palmer, and K. Richards. 2013. Enhancing water security for the

775   benefits of humans and nature—the role of governance. *Current Opinion in*

776   *Environmental Sustainability* 5-6: 676-684.

777

778   Paisley, R., and T. Henshaw. 2013. Transboundary governance of the Nile River Basin:

779   Past, present and future. *Environmental Development* 7: 59-71.

780

781   Palmer, M. 2012. Socioenvironmental sustainability and actionable science. *BioScience*

782   62: 5-6.

783

784   Palmer, M., C. Reidy Liermann, C. Nilsson, M. Flörke, J. Alcamo, P.S. Lake, and N.

785   Bond. 2008. Climate change and the world's river basins: Anticipating management

786   options. *Frontiers in Ecology and the Environment* 6: 81-89.

787

788   Pielke, R. 2007. *The honest broker: Making sense of science in policy and politics*.

789   Cambridge: Cambridge University Press.

790

791   Raadgever, G. T., E. Mostert, N. Kranz, E. Interwies, and J.G. Timmerman. 2008.

792   Assessing management regimes in transboundary river basins: Do they support adaptive

793   management? *Ecology and Society* 13: 14. [online] URL:

794   http://www.ecologyandsociety.org/vol13/iss1/art14/

795

796   Raik, D., A. Wilson, and D. Decker. 2008. Power in natural resources management: An

797   application of theory. *Society and Natural Resources* 21: 729-739.

798

799   Reed, M.S., A.C. Evely, G. Cundill, I. Fazey, J. Glass, A. Laing, J. Newig, B. Parrish, et

800   al. 2010. What is social learning? *Ecology and Society* 15: r1. [online] URL:

801   http://www.ecologyandsociety.org/vol15/iss4/resp1/

802

803   Rittel, H.W.J., M.M. Webber. 1973. Dilemmas in a general theory of planning. *Policy

804   Sciences* 4: 155-169.

805

806   Roux, D.J., K.H. Rogers, H.C. Biggs, P.J. Ashton, and A. Sergeant. 2006. Bridging the

807   science-management divide: Moving from unidirectional knowledge transfer to

808   knowledge interfacing and sharing. *Ecology and Society* 11: 4. [online] URL:

809   http://www.ecologyandsociety.org/vol11/iss1/art4/

810

811   Sabatier, P.A., W. Focht, M.N. Lubell, Z. Trachtenberg, A. Vedlitz, and M. Matlock (ed.).

812   2005. *Swimming upstream: Collaborative approaches to watershed management*.

813   Cambridge: MIT Press.

814

815   Scott, C.A., R.G. Varady, F. Meza, E. Montaña, G.B. de Raga, B. Luckman, C. Martius.

816   2012. Science-policy dialogues for water security: Addressing vulnerability and

817   adaptation to global change in the arid Americas. *Environment Magazine* 54: 30-42.

818

819   Sutherland, W.J., D. Spiegelhalter, and M. Burgman. 2013. Twenty tips for interpreting

820   scientific claims. *Nature* 503: 335-337.

821

822   Taylor, B., and R. de Loë. 2012. Conceptualizations of local knowledge in collaborative

823   environmental governance. Geoforum 43:1207-1217.

824

825   Timmerman, J. G., and S. Langaas. 2004. *Environmental information in European*

826   *transboundary water management*. London: IWA Publishing.

827

828   Timoney K.P. and P. Lee. 2009. Does the Alberta tar sands industry pollute? The

829   scientific evidence. The Open Conserv Biol J 3: 65–81.

830

831   Toderi, M., N. Powell, G. Seddaiu, P. Roggero, and D. Gibbon. 2007. Combining social

832   learning with agro-ecological research practice for more effective management of nitrate

833   pollution. *Environmental Science and Policy* 10: 551-563.

834

835   Turton, A., P. Ashton, and E. Cloete. 2003. An introduction to the hydropolitical drivers

836   in the Okavango River basin. In *Transboundary Rivers, Sovereignty and Development:*

837   *Hydropolitical Drivers in the Okavango River Basin*, ed. A. Turton, P. Ashton, and E.

838   Cloete, 7–30. Pretoria: African Water Issue Research Unit, Green Cross.

839

840   United Nations Educational, Scientific, and Cultural Organization (UNESCO). 2009.

841   Atlas of transboundary aquifers: global maps, regional Cooperation, and local inventories.

842   International Hydrological Programme, Paris.

843

844   United States Department of the Interior. 2012. Colorado River Basin water supply and

845   demand study. Bureau of Reclamation. Retrieved 9 September, 2014, from

846   http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/index.html

847

848   Vogel, C., S.C. Moser, R.E. Kasperson, and G.D. Dabelko. 2007. Linking vulnerability,

849   adaptation, and resilience science to practice: Pathways, players, partnerships. *Global*

850   *Environmental Change* 17: 349-364.

851

852 Vörösmarty, C., P. Green, J. Salisbury, R.B. Lammers. 2000. Global water resources:

853 Vulnerability from climate change and population growth. *Science* 289: 284-288.

854

855 Wallis, P., and R. Ison. 2011. Appreciating institutional complexity in water governance

856 dynamics: A case from the Murray-Darling Basin, Australia. *Water Resources*

857 *Management* 25: 4081-4097.

858

859 Wallis, P., R. Ison, and K. Samson. 2013. Identifying the conditions for social learning in

860 water governance in regional Australia. *Land Use Policy* 31: 412-421.

861

862 Wallis, P., B. Iaquinto, R. Ison and R. Wrigley 2015. Governing irrigation renewal in

863 Australia, *International Journal of Water Governance* (in press).

864

865 Weller, P., and M. Popovici. 2011. Danube River Basin Management – rationale and

866 results: How to link science, as the basis for policy. *River Systems* 20: 103-109.

867

868 Wolfe, B.B., D. Armitage, S. Wesche, B.E. Brock, M.A. Sokal, K.P. Clogg-Wright, C.L.

869 Mongeon, M. Adam, et al. 2007. From isotopes to TK interviews: Towards

870 interdisciplinary research in Fort Resolution and the Slave River Delta, Northwest

871 Territories. *Arctic* 60:75-87.

872

873   Wolfe, B.B., R.I. Hall, T.W.D. Edwards, and J.W. Johnston. 2012. Developing temporal

874   hydroecological perspectives to inform stewardship of a northern floodplain landscape

875   subject to multiple stressors: paleolimnological investigations of the Peace-Athabasca

876   Delta. *Environmental Reviews* 20: 191-210.

877

878   Zeitoun, M., and J. Warner. 2006. Hydro-hegemony - a framework for analysis of

879   transboundary water conflicts. *Water Policy* 8: 435-460.

880

881   Zeitoun, M., and N. Mirumachi. 2008. Transboundary water interaction I: Reconsidering

882   conflict and cooperation. *International Environmental Agreements* 8: 297-316.

883

884   Zeitoun, M., M. Goulden, and D. Tickner. 2013. Current and future challenges facing

885   transboundary river basin management. *Wiley Interdisciplinary Reviews: Climate Change*

886   4-5: 331-349.

887

888

Table 1: Overview of selected transboundary water basin science-policy successes and challenges

Transboundary basin	Key issues, successes and challenges
Colorado Drainage area: 640,000 km^2 River length: 2,334 km Average annual natural* flow: 641 m^3/s Average annual actual flow, measured at the southern international border: 75.3 m^3/s Population: 40 million Jurisdictions: 10 (international)	<u>Issues</u> • Over-allocation, anticipated increased duration and severity of drought, growing population and demand for water <u>Successes</u> • Emerging *network* of science, government and non-government actors that has facilitated research coordination for the lower Colorado River • Increased deliberation and collaboration focused on critical needs relating to environmental flow and allocation reflecting key concerns and illustrating new opportunities for use different types of *knowledge* and opportunities for *learning* among different actors <u>Challenges</u> • Establishing formal, long-term processes for stakeholder engagement that sustain collaboration and knowledge sharing through time • Balancing competing values about water use among upstream and downstream users with different levels of *power*
Mackenzie Drainage area: 1.8 million km^2 River length: 4,241 km Average annual flow: 9910 m^3/s Population: 397,000 Jurisdictions: 7 (sub-national)	<u>Issues</u> • Anticipated flow reductions, existing and proposed hydroelectric development and increased human demand for water from industry; anticipated increases of pollution from oil sands mining and processing; Aboriginal populations and competing values about water use <u>Successes</u> • Development of multi-stakeholder monitoring partnerships that proactively link communities, researchers and governments and that have built upon existing informal networks • Strong emphasis in basin on incorporating science and traditional *knowledge* in decision making • Innovative measures to create *positive conditions early on* for decision making processes by embedding credible scientists on land and water boards <u>Challenges</u> • Developing and implementing effective, long-term inter-jurisdictional and trans-jurisdictional water management agreements given significant power asymmetries and competing interests among jurisdictions • Developing science-policy processes that reflect local considerations in the broader water stewardship context • Capacity building among traditional knowledge-based actors and in circumstances where there are historical and continued distrust among government agencies, industries, southern-based scientists and local and Aboriginal organizations
Mekong Drainage area: 760,000 km^2 Average annual flow: 14,500 m^3/s	<u>Issues</u> • Existing and proposed hydroelectric facilities, asymmetric cooperation among basin states and the role of the Mekong River Commission (convened by Laos, Thailand, Cambodia and Vietnam), poverty and economic development pressures

41

River length: 4,909 km Population: 70 million Jurisdictions: 6 (international)	<u>Successes</u> • Emergence of civil society-based *network* using action-based research to inform and open-up decision making vertically and horizontally • Potential for alternative track to the official inter-state negotiations given role of Mekong River Commission as *boundary organization* – i.e., connecting actors through *shadow* networks <u>Challenges</u> • Capacity building for the development of different kinds of *knowledge* held by various stakeholders and ways to include them in the decision-making process – *science as one input* to decision making processes can preclude the views and inputs of more marginalized communities in Mekong context • Addressing hydropower projects that are not necessarily state-led projects but in the form of public-private partnerships and build-own (-operate)-transfer schemes – these initiatives may emerge in absence of legitimate and transparent processes and undermine *initial conditions* needed for collaboration among science, policy and community actors
Murray-Darling Drainage area: 1,064,469 km^2 Average annual natural* flow: 409 m^3/s Average annual actual flow: 161 m^3/s River length: Darling 2,740km Murray 2,530 km Population: 2.1 million Jurisdictions: 5 (sub-national)	<u>Issues</u> • Water quantity and water quality, flow fragmentation, historical over allocation, ecological rehabilitation; effective implementation and adaptation of a new whole-of-basin plan in conditions where 'co-operative Federalism' is breaking down once more <u>Successes</u> • Institutionalization of environmental flows and Federal and State offices of an Office of Environmental Water Holder help create *initial conditions for better decisions* over the longer term • Scientific input into the Water Basin Plan and evaluative reviews conducted by the former National Water Commission illustrates effective *learning* given past gaps in linking scientific inputs into formal decision making • Market mechanisms employed for buy-back of over-allocated water reflect awareness of need for diverse solutions and perspective (i.e., industry) and also reflect increased awareness that *science is ultimately one input* • Trading of water rights and/or allocations has expanded economic opportunity for irrigators and increase options for environmental buyback <u>Challenges</u> • Sustaining effective river governance across all sub-catchments in the face of state and regional institutional diversity and lack of security of funding to local organisations reflecting an inability to forge a coherent *network* to support science and policy • Future national policy setting is uncertain with the demise of the National Water Commission which was charged with oversight of delivery of the National Water Initiative suggesting some important *initial conditions* for collaboration and science-policy interaction are not in place. • Uncertain implementation and adaption of the National Plan in the face of climate change and potential institutional failure indicating science inputs will need enhanced institutional networks and institutionalization of *learning* through change

| **Orange-Senqu**
Drainage area: 896,368 km²
Average annual flow: 364 m³/s
River length: 2,200 km
Population: 19 million
Jurisdictions: 5 (international) | <u>Issues</u>
• Flow fragmentation, declining water quality and variability of quantity, ecological health, human and financial capacity constraints; major challenges related to collection of data needed to make decisions

<u>Successes</u>
• Institutionalized body (Orange-Senqu River Commission: ORASECOM) established in 2000 which has the potential to serve as *boundary organization* and encourage opportunities for learning
• Joint Water Quality Baseline Survey conducted by a joint research team of scientists from each of the member states as well as members from the ORASECOM enhanced efforts to bridge perspective and *knowledge* needed to measure key ecological components and function as a baseline against future 5-year surveys

<u>Challenges</u>
• Despite presence of an important boundary organization (i.e., the Commission), limited success establishing public participation processes that are sustainable and feed into decision-making has limited opportunities for meaningful *learning* and efforts to build vertical and horizontal *networks* |
| **Danube**
Drainage area: 801,463 km²
Average annual flow: 6,550 m³/s
River length: 2,857 km
Population: 82 million
Jurisdictions: 19 (international) | <u>Issues</u>
• Pollution, flood protection / prevention and ecological rehabilitation (e.g., delta)

<u>Successes</u>
• Long-standing and institutionalized *boundary organization* (International Commission for the Protection of the Danube River) established in 1994 to build capacity to link science and policy across 19 jurisdictions
• Major reductions in pollution, increased basin-wide monitoring and regular Joint Danube Surveys to guide management actions reflect on-going process of *knowledge co-production* and *learning*

<u>Challenges</u>
• Demonstrating improvements in ecological conditions remains a challenge reflecting need communicate story of success *beyond the science*
• Coordination among diverse institutions in region because of various capacity and organizational issues undermines network of actors and constrains establishment of *conditions* needed for long-term success |

891
892
893
894

Sources: US Department of the Interior 2012; Gerlak et al. 2013; Earle et al. 2005; Huisman et al. 2000; MRBB 2003; MRC 2010; MDBC, 2003; ORASECOM 2010; Wolfe et al. 2012; Government of Canada 2010; N.B.: Over the past decade, the authors have worked on a range of natural and social science studies in all of these basins

895
896 **Box 1: Science, policy and transboundary water governance in the Mackenzie Basin,**
897 **Canada**
898

The Mackenzie River Basin (MRB) drains approximately 20% of Canada's landmass within the provinces of British Columbia, Alberta, Saskatchewan, as well as Yukon Territory, the Northwest Territories (NWT) and Nunavut. Despite being located within one country, this enormous basin is truly transboundary because of the control these political jurisdictions have over water in Canada's federation. The MRB's headwaters begin in the Peace and Athabasca sub-basins in British Columbia and Alberta, respectively, which converge at the Peace-Athabasca Delta in Alberta. The system flows north as the Slave River into the Northwest Territories, which eventually becomes the Mackenzie River and drains into the Arctic Ocean. Upstream jurisdictions (notably Alberta) are conventionally thought of as having significantly more power than downstream jurisdictions (notably the Northwest Territories). The MRB hosts internationally- and culturally-significant deltas and wetlands that are staging and breeding grounds for a variety of migratory birds and are important to local aboriginal communities. Freshwater discharge from the Mackenzie River has a globally significant role in regulating ocean and climate systems (MRBB 2003).

Climate variability is emerging as a key driver of uncertainty in water levels and flood frequency in the deltas, and the weight of evidence points to long-term water availability decline in the upper MRB (Wolfe et al. 2012) with long-term consequences for aquatic ecosystems of global significance. The basin also figures prominently in plans for resource development in Canada, which include hydroelectric and mining projects in the Peace and Athabasca sub-basins and the potential expansion of mining and oil and gas development (including fracking) in downstream Northwest Territories. In the face of climate and development drivers, better science-policy processes to preserve environmental flows is a vital component of transboundary water governance in this basin.

Foundations for better science-policy processes have emerged in several crucial ways. For example, a number of ecological monitoring programs that seek to link scientific and traditional knowledge have been developed for important parts of the MRB. The Peace-Athabasca Delta Ecological Monitoring Program (PADEMP) is an effort in knowledge co-production between federal, provincial, territorial, indigenous governments and environmental non-governmental organizations. Participants are jointly identifying vulnerabilities and key ecological monitoring priorities in the Peace-Athabasca Delta that will be cooperatively evaluated. More recently, the Slave River and Delta Partnership (SRDP) was created to facilitate community-based monitoring in response to local concerns regarding ecosystem health. Actors involved include the federal, territorial and aboriginal governments, academic institutions and local residents. Key outputs thus far have included improved partnerships and understanding, state of knowledge and vulnerability assessment reports, and a greater voice for communities in water-related decisions.

The SRDP is an outcome of efforts to establish conditions for future success, including the development (and associated implementation plan) of the Northwest Territories Water Stewardship Strategy (2010), and initiatives to build science capacity into land and water management boards. For example, the Mackenzie Valley Land and Water Board has developed science-based policies and procedures that have directly resulted in wiser decisions that most observers conclude have protected ecological integrity while preserving the profitability of industrial operations. Credible decisions have also strengthened the Board's relations with government agencies and industry, and have fostered trust-building with aboriginal governments and peoples, thus contributing to its role as a bridging organization.

Monitoring partnerships and other science-policy initiatives are relatively recent ventures, and their long-term success is uncertain. However, they do display some of the key characteristics of successful science-policy integration including building greater integration among scientists, policy makers and non-state actors (aboriginal interests in particular); emphasizing social or group learning processes; fostering the collaborative production of knowledge about hydrological change and the range of possible governance responses; and recognizing how science is a crucial but bounded part of the sustainability dilemma in transboundary water governance settings. The challenge remains to institutionalize gains made in an adaptive manner and to scale up science-policy processes for the longer term.

899
900