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Title: Tracking cultural ecosystem services: Water chasing the Colorado River restoration pulse flow

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Highlights

- We track cultural ES dynamics of a restoration flow.
- Monitoring of e-flows typically neglect the social response.
- Socio-hydrologic case studies can inform science and policy.

Abstract

The release of environmental flows for ecological restoration is a challenge for water policymakers and managers as it involves complex trade-offs between productive and ecosystem uses of water. While it is crucial to demonstrate that such environmental flows produce the desired hydro-ecological results, allocation of environmental water is also influenced by perceived social values of this water. This research draws on the sub-field of socio-hydrology to track two-way feedbacks between humans and environmental flows and shows why and how social responses to river restoration can be monitored. Media coverage, posted comments and in-person interviews were used to track the responses of stakeholders who 'chased' the progress of the 2014 "pulse flow" down the Colorado River. These data framed in the cultural ecosystem systems typology revealed the temporal patterns and dynamics of dramatic shifts in socio-hydrologic processes and highlight the value of understanding the human wellbeing benefits and complex social values that are affected by freshwater restoration. This experimental and mixed evidence approach is useful for contexts where multiple stakeholders shape water resource management and we suggest it can be used by water decision-makers in their efforts to understand and appropriately respond to the social-ecological dynamics of a changing river system.

Keywords

Transboundary, restoration, pulse flow, social values, socio-hydrology, monitoring, cultural ecosystem services, public good

1. Introduction

The Colorado River has long been viewed as a 'frontier' that marks the enduring American theme of subjugating wilderness to serve national needs: "a vision of lonely lands made fruitful", in the words of the plaque atop Hoover Dam. This enduring ideology has justified the river being 'tamed' by large dams and aqueducts and a water policy that has reduced the diversity of the basin's cultural and ecological terrains to serve irrigated agricultural production and urban development. Until 2014, there had been no allocation of water for the river's habitats in its delta. In most years since 1960 and the completion of the two main dams on the river (Hoover Dam creating Lake Mead and Glen Canyon Dam creating Lake Powell), the river ran dry before it reached the sea.

Recent water planning reforms have marked a shift towards a sustainable reconciliation with the land and its people. River flows have been created in sections of the Colorado River for the enjoyment of rafters [Patten et al., 2001], ecosystems [Meretsky et al., 2005] and water rights of Native American communities [Hundley, 2009]. Conventional environmental and cultural understandings of the river are slowly being decoded, recalled and re-negotiated. On the ground, this trend necessarily re-introduces local people's interpretations and expressions of their relationships to the river. In theory it has led to the development of the new sub-field of socio-hydrology [Sivapalan et al., 2012; see Blair and Buytaert 2015 for a review] which is explicit about the "two-way feedbacks between human and water systems" [Sivapalan et al., 2014: 225].

Sivapalan et al., (2014) call for the study of real-world systems as a means to understand human-water dynamics; we propose that the study of environmental flows in fully allocated river basins for ecological restoration of riverine and/or estuarine ecosystems is a fertile one to discover these dynamics. This is because it offers means to explore if and how culture adapts and changes with environmental change [Caldas et al., 2015]. Cultural dimensions of water can underpin tensions between stakeholders in over-allocated basins. The decision to allocate environmental water can add to this conflict and be a difficult and contentious task [Szemis et al., 2013]. At the same time water managers are seeking to utilize and quantify information about human water values and preferences so that it can inform decision-making mechanisms such as hydrological models (Jacobs et al. 2012)

Three lines of enquiry in socio-hydrology–historical, comparative and process–have been suggested [Sivapalan et al., 2012; Sivapalan and Blösch, 2015]. In practise this requires data collection and analysis that explains interactions between people and water and subsequent conversion of such evidence into metrics that can be used to inform water planning and decision-making. There is a small but growing area of scholarship that has considered how a better understanding of nature-society inter-relationships can be useful to water managers in operational planning [Bark et al., 2015; Robinson et al., 2014]. In this research we find that such information could also be useful in restoration decisions.

There are two key questions related to collecting such data: *why* monitor? and monitor *what* (how and when)? To answer the *why* question, monitoring provides evidence not just anecdotes about success [Kondolf et al., 2007] and information for adaptive management [Harris and Heathwaite, 2012] and to answer the *what* question in relation to the effectiveness of restoration, Palmer et al., [2005] suggest that there are three axes to measure: ecological success, learning success and stakeholder success. The pulse flow on the Colorado River was part of an agreement,

Minute 319.[1] The Minute incorporates monitoring to measure the ecological success of the pulse flow, specifically an evaluation of "the ecosystem response, most importantly the hydrological response and, secondarily, the biological response" [IBWC, 2012, Sec 6,c, iv]. This monitoring effort continues through 2017 and involves binational teams of scientists from U.S. and Mexican universities, government agencies and environmental NGOs [Flessa et al., 2013; Flessa et al., 2014].

The (adaptive) learning dimension is intrinsic in the experimental nature of the pulse flow event, however, here we broaden this to also assess institutional and international learning, as well as, learning about the process of restoration [Eden and Tunstall, 2006; Pahl Wostl et al.,2007].

The third dimension, of stakeholder success, is absent from the monitoring plan. To answer the why monitor, social responses may add to greater understanding of social values which is key to assess public support for river restoration [Loomis, 2006; Trabucchi et al., 2012], to the design of incentives for restoration activities [Seidel and Stauffacher, 2013], and to improve the uptake of restoration activities [Eden et al., 2000; Eden and Tunstall, 2006; Schlapfer and Witzig, 2006; Jacobs et al., 2012; Robinson, et al., 2014]. Generating data on the interaction of biophysical and human dimensions of restoration [Sivapalan et al., 2014] and the competition among different stakeholders [Sivapalan and Blösch, 2015] is a key goal of this paper.

Therefore, to answer the what dimension we first have to define the stakeholders. The literature on stakeholders is extensive [see Reed et al., 2009], here we identify stakeholders in the pulse flow event as those actors who are involved in restoration planning and design, local people and observers directly participating in the event, and the wider public that engage with media on the event. To answer the how and when dimensions we use three different data sources – content analysis of media coverage, on-site semi-structured interviews, and direct observations – thereby sampling different cultural processes affecting stakeholder values [Caldas et al., 2015] over the period of the restoration flow.

The paper proceeds with some background on the pulse flow, the methods used, results on tracking social responses to the pulse flow, and a discussion of the usefulness of such monitoring to the study of socio-hydrology, for water management, and restoration policy.

2. Background

Bark et al., [2014] provide background on the administration of the Colorado River system and the history of Minutes leading up to Minute 319 [IBWC, 2012]. The pulse flow implemented in 2014 as the result of Minute 319 has been lauded as a major breakthrough in Colorado River water management [Festa and Enstminger, 2014] and is the result of decades of negotiations. The actual timing of the pulse flow was, however, inauspicious. Although not supplied with water from the Colorado River, northern California was in the grip of a serious drought in spring 2014. Fears were widespread that Lake Mead, a critical storage reservoir, would drop below a critical level and trigger downstream rationing [Jerla et al., 2011]. Adding to the anxiety, the U.S. Bureau of Reclamation, the water manager in the U.S. portion of the basin, had pointed out that rising demand had already exceeded supply and that projected climate change impacts would make matters worse [USBR, 2012].

[1] A Minute, as opposed to an amendment, is a mutual agreement for modifications to a treaty in this case the 1944 treaty between the United States of America and Mexico that governs the transboundary "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande."

Concerns that the Minute 319 pulse flow would not be well-received in such a climate of scarcity were widespread within the river management agencies and environmental NGOs of both countries. Pre-pulse flow messages emphasised: 1) the small amount of water involved; 2) that the flow itself was a planned experiment that would add to the body of knowledge on how best to approach riparian restoration [e.g. Flessa et al., 2013]; and 3) that it was a symbol of a new era of cooperation that heralded a new and a mutually beneficial approach to river management.

The pulse flow began on March 23, 2014 when the diversion dam at the border between the U.S. and Mexico, Morelos Dam was opened and pulse flow water began to flow down the dry river bed. The flow was slow enough to walk in front of; it was however not predictable in all places which branch(es) of the old river bed it would flow in, prompting the term "water chaser" for those who tracked its downstream progress. Water releases for the pulse flow peaked on April 27. The hydrograph of the pulse flow was developed to both mimic a spring flood and to ensure that flows reached restoration sites, see Fig. 1. On May 15, 2014 the river reached the sea, see Fig. 2. Flows ceased on May 18, 2014.

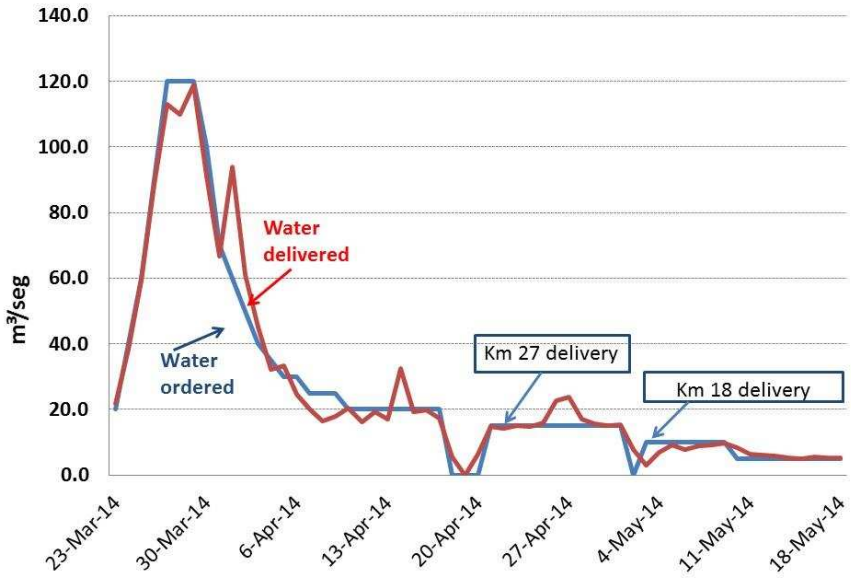

Fig. 1. Pulse flow hydrograph: actual vs planned (source: the United States Bureau of Reclamation). Note: Differences between actual and planned releases are the result of complex river management operations to meet multiple demands in the Lower Basin. Deliveries were also made at the 18km and 27km points via irrigation canals to ensure water researched restoration sites.

Fig. 2. Colorado River (upper) approaching tidal channel of Gulf of California (lower) on May 12, 2014. Photo credit: Francisco Zamora, Sonoran Institute, with aerial support from Lighthawk.

3. Methods and data

We drew on socio-hydrology to interrogate media reports about the pulse flow, posted comments, semi-structured interview responses and observation to address the three goals of socio-hydrology, which are to: (S-H1) analyse the temporal patterns and dynamics of socio-hydrologic processes; (S-H2) understand and interpret socio-hydrologic processes on human wellbeing; and, (S-H3) understand the value of water culturally, politically (and economically) [Sivapalan et al 2014; see Bark et al., 2014 for a review of the economics of this transboundary flow].

Media reports on the pulse flow were collected between December 30, 2013 and June 14, 2014 using a daily Google News Alert and Google News searches using the search keywords: "Colorado River Delta", "Colorado Delta", "pulse flow", and "Minute 319". The period chosen was longer than the restoration event to pick up early analysis of the event and later reflection on the event. A total 263 reports comprising newspaper articles, radio and TV broadcasts, news websites and blog posts made up the dataset. We counted each publication or posting of an article, including those produced by a wire service such as the Associated Press. We included editorials and op-ed columns. We did not count each individual broadcast of the National Public Radio or the BBC World Service stories as single stories are broadcast on multiple stations at multiple times. We did not count press releases from government agencies, conservation groups or universities unless they were reposted by another outlet. Our count may underestimate the total coverage as we likely missed some items, and some posts had already been taken down by the time of our survey; however the temporal pattern is likely captured.

This core dataset was analysed in two ways, using a simple categorisation of posted comments and with content analysis software. Many of the stories had a large number of posted comments that we reviewed. We counted comments, not individual authors of the comments.

Comments were categorised as supportive, negative or other. To further analyse the content of the qualitative media data we used dedoose (sometimes Dedoose) software (http://www.dedoose.com/). The full dataset incorporates a number of Associated Press and other wire service articles that were reproduced by different media outlets. Excluding these duplicates resulted in a sub-set of 153 media articles which were imported into dedoose. Excerpts, from a fragment of a sentence to a full paragraph, in each media article were coded. For each excerpt we coded two pieces of information. We used Chan et al.,'s (2012) cultural ecosystem services (CES) framework and a time stamp to reveal the dynamics of human care and concern generated over the life cycle of the pulse flow event.

Chan et al., (2012) identify 12 types of CES. These are Activity, Aesthetic, Employment, Existence/bequest, Identity, Inspiration, Knowledge, Material, Option, Place/heritage, Social capital & cohesion, Spiritual. In coding, "Activity", comprised those excerpts that mentioned "Binational *collaboration* and *negotiation*" and "*Exercising* a bilateral agreement (Minute 319)", whilst a code for "Knowledge" was a mention of the pulse flow as an *experiment*, or mention of biophysical and ecological *monitoring* and other *learning*/*demonstration* opportunities. We coded specific mention of the pulse flow as "Option" if an option value was specifically mentioned, or, if the NGO-led *"Raise the River"* campaign to raise money from the general public (most donors are unlikely to visit the delta) to purchase water rights from Mexican farmers for the long-term health of the river [see Bark et al., 2014] was mentioned. In addition to the Chan et al., (2012) 12 CES codes we also coded for a new category of CES, "Aspiration" suggested by Bark et al., (2015). They found aspiration to be central to an Aboriginal community's interaction with their water environment and water planning frameworks in Australia.

The coding exercise provided information on how many times each individual CES was written about in each article and across the dataset and thus provided information for goals S-H2 and S-H3. We also coded each article with one of six time stamps representing a phase of the pulse flow: Pre, Start, Peak, Flows, Connect, and Post. Of 153 articles, 25, 15, 35, 35, 33, 10 articles, respectively fell in these time periods. The addition of this temporal information enables the creation of more complex relationships to view potential patterns in the types of and the dynamics of those CES written about prior to, during and after the pulse flow, i.e. to better understand the socio-hydrological dynamics of restoration.

Additionally, 25 semi-structured interviews were conducted at or near the March 27, 2014 bi-national ceremony on top of the Morelos Dam, Los Algondones, Baja California, Mexico. The ceremony coincided with the peak of the pulse flow, see Fig. 1. The sample clearly was taken from a population interested in the pulse flow. In addition it was not stratified by citizenship, gender, employment, or other factors, rather, potential interviewees were approached, signed a consent form, and their responses were written down. Twenty of the interviews were conducted in English and five in Spanish. Of the total, nine were Mexican citizens and sixteen U.S. citizens. Interviewees were asked their professional affiliation, their relationship to the river, the reason for their attendance, and to comment on their feelings about the pulse flow, the likely benefits stemming from the pulse flow, its timing, and whether it should occur again. Finally, two of the authors of this paper observed people engaging with the pulse flow around the peak flow period near the town of San Luis Río Colorado, Sonora, Mexico, see Fig. 3.

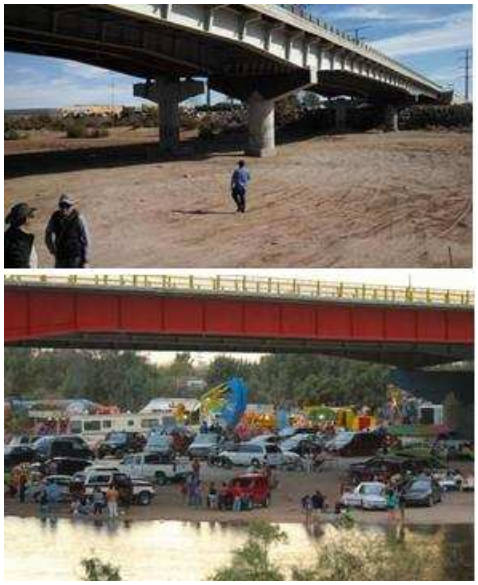

Fig. 3. Highway bridge crossing Colorado River near San Luis Río Colorado, Sonora, Mexico. A. (Upper) Dry river bed prior to pulse flow. Photo credit: Eloise Kendy, The Nature Conservancy. B. (Lower) River during pulse flow. Photo credit: Osvel Hinojosa, Pronatura Noroeste

4. Tracking social responses to restoration flows

We present our results that track social responses to the pulse flow by data source, i.e. media articles, media article comments and semi-structured interviews. Although we coded for six time phases, Pre, Start, Peak, Flows, Connect, and Post, the results here exclude excerpts from the Flows phase. The flows category is not a discrete time period as it includes those articles from all other non-specified time periods, i.e. between Start and Peak, and, Peak and Connect.

4.1 Media articles

To set the scene Table 1 provides a sample of media headlines over the pulse flow. As can be seen from this sample the majority of headlines are positive.

Table 1 Examples of media coverage headlines with date and outlet.

Date	Headline	Outlet
March 10	A pulse of life at the mouth of the Colorado	Las Vegas Review-Journal
March 17	Ignoring drought, U.S. to divert water to Mexico for environmental project	Breitbart Report
March 27	Colorado River begins flooding barren delta on the border, brings hope to thousands	Foxnews Latino
April 10	Infusion of river water hits restoration site	San Diego Union-Tribune
April 25	U.S., Mexico collaborate to boost Colorado River delta	Mohave Valley Daily News
May 21	Colorado River finally reunited with sea	Foxnews.com
May 23	International effort to revive the Colorado delta	Arizona Public Media

Next using the entire 263 media item records we tracked the temporal profile of coverage in Fig. 4. We note that the coverage intensity tracked the pulse flow hydrograph (Fig. 1) reaching a peak during the week of the first flows and formal ceremonies and then tapering off in the following six weeks. However, unlike the pulse flow hydrograph, coverage peaked again in the final week of the eight-week peak flow; this disconnect between the hydrograph and the graph of the media coverage is suggestive of other factors at play. The second peak in media coverage coincided with the connection of the pulse flow with the Gulf of California: marking the first time, i.e. symbolic and media worthy, the river had reached the sea since 1998 (Fig. 2).

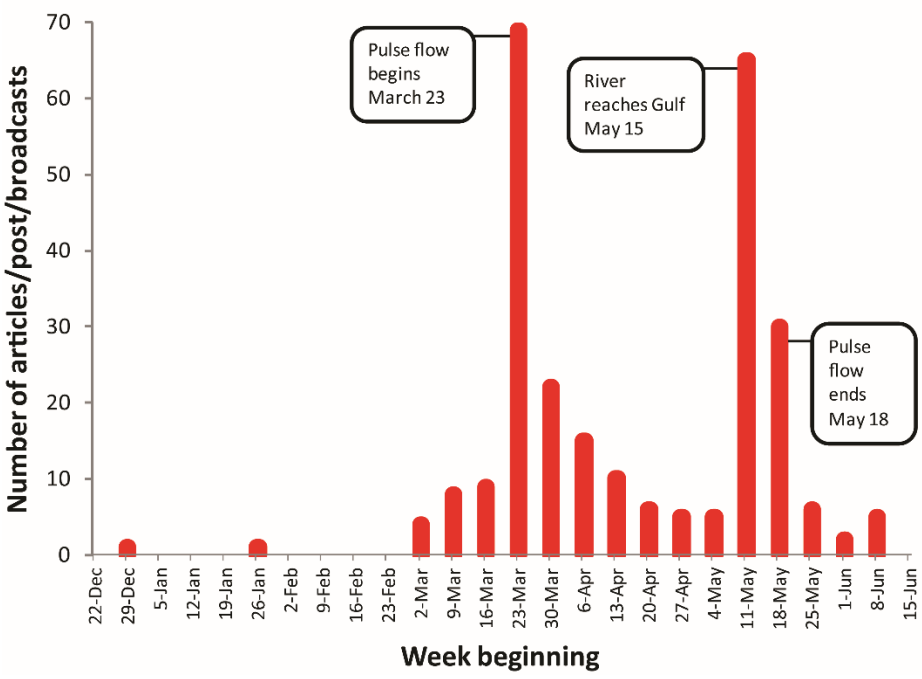

Fig. 4. English language media coverage of Minute 319 pulse flow from January 1 through June 14, 2014.

Content analysis provided a means to link the temporal nature of media attention with the specifics of each article, coded by CES, and thus a lens to see what type of information was provided to the reading public. The raw data, i.e. number of excerpts in each CES category by time phase are shown in Fig. 5. The chart shows the dominance, in count terms, of the Activity category. The pulse flow was a big story and the precedents for the pulse flow, international collaboration and the exercise of the bilateral Minute 319 agreement, were well reported.

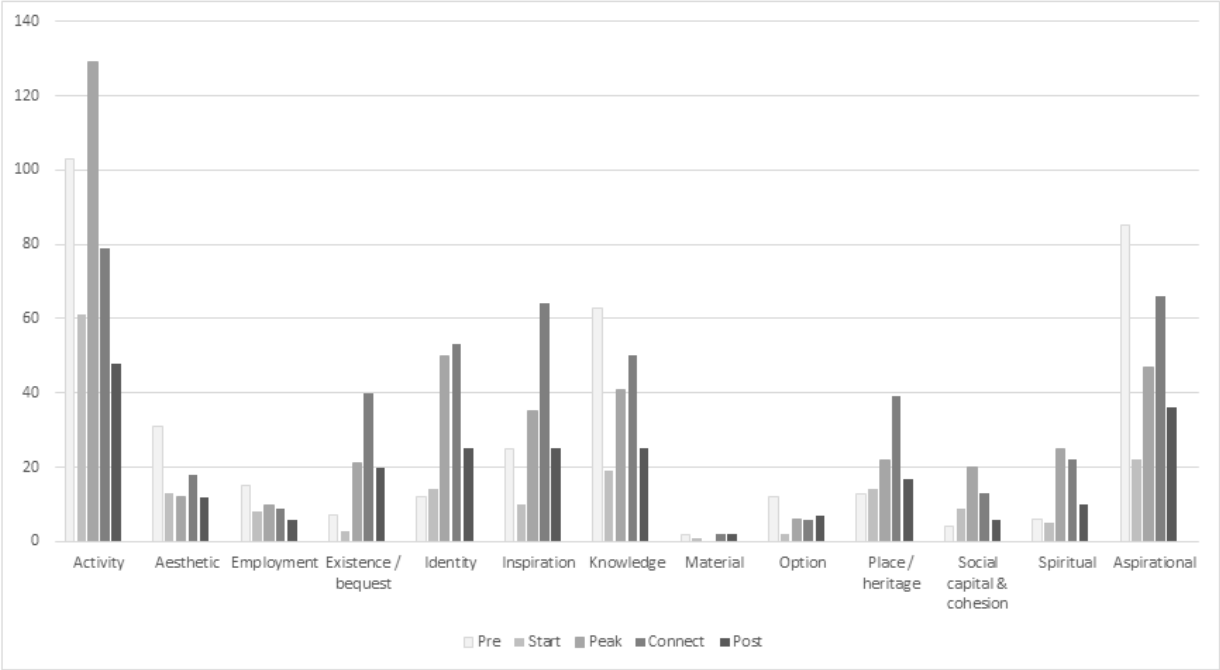

Fig. 5. dedoose content analysis: Number of excerpts coded with Chan et al.,'s (2012) CES and by pulse flow phase

To aid in pattern recognition Table 2 shows the proportion of total excerpts coded by CES by pulse flow phase, not the actual number of excerpts coded. We divide the time phases into Antecedents (Pre), Engagement with the pulse flow event (Start, Peak, Connect) and Reflection (Post). For each CES, we shade in dark grey the time phase with the largest proportion of excerpts and light grey for the next highest.

Table 2 Proportion of excerpts coded in each CES category (Chan et al., 2012) by pulse flow phase.

Phase / Category	Antecedents	----- Engagement -----			Reflection
	Pre	**Start**	**Peak**	**Connect**	**Post**
Activity	0.25	0.15	0.31	0.19	0.11
Aesthetic	0.36	0.15	0.14	0.21	0.14
Employment	0.31	0.17	0.21	0.19	0.13
Existence / bequest	0.08	0.03	0.23	0.44	0.22
Identity	0.08	0.09	0.32	0.34	0.16
Inspiration	0.16	0.06	0.22	0.40	0.16
Knowledge	0.32	0.10	0.21	0.25	0.13
Material	0.29	0.14	0.00	0.29	0.29
Option	0.36	0.06	0.18	0.18	0.21
Place / heritage	0.12	0.13	0.21	0.37	0.16
Social capital & cohesion	0.08	0.17	0.38	0.25	0.12
Spiritual	0.09	0.07	0.37	0.32	0.15
Aspiration	0.33	0.09	0.18	0.26	0.14

Antecedent CES which dominate comprise Aesthetic, Employment, Knowledge, Option and Aspiration. During Engagement with the flow, there are no shaded boxes in the Start phase, the first few days of the pulse flow. However, in many CES categories Peak or Connect are shaded dark grey and the other light grey, i.e. Existence/bequest, Identity, Inspiration, Place/heritage, Social capital & cohesion, and Spiritual. Meanwhile, Activity, i.e. discussion of the pulse flow binational collaborative event, stands out during the Peak phase, when there was a binational ceremony, and Aesthetic, Knowledge, and Aspiration during Connection. In the Post pulse flow Reflection phase the articles are focused on Existence/bequest of the latterly reborn river and the Option for a second pulse flow; both are shaded light grey.

Finally in Table 3 we provide a breakdown of a single CES code, Knowledge. The knowledge category consisted of five different sub-codes for: biophysical, ecological, and experimental knowledge as well as for uncertainty and institutional and international learning. See Table 3 for a breakdown. (Note the individual numbers do not add up to the total as excerpts could be coded for multiple sub-codes).

Table 3 Breakdown of Knowledge cultural ES coding.

	Biophysical monitoring	Ecological monitoring	Experiment	Uncertainty and learning	Institutional learning, model for world	Total
Pre	19	20	49	11	2	63
Start	7	6	13	4	1	19
Peak	14	10	32	2	4	41
Connect	22	13	40	11	8	50
Post	9	9	16	7	9	25

Overall the acquisition of Knowledge was frequently written about and this code shows the progression of learning underpinning the pulse flow. Many articles articulated the experimental nature of the pulse flow and of the experimental learning and monitoring embedded in Minute 319 that was designed to reduce uncertainty and improve restoration science. Near the end of the pulse flow was acknowledgement of the international learning that would benefit from studying the antecedents of the pulse flow and its implementation as well as recognition that the human dimensions of the pulse flow had been initially underestimated.

4.2 Media comments

We did not use content analysis software on the public comments to the media articles, rather, we report a simple categorisation of comments. Of the total 1,796 public comments reviewed from 81 sites, we categorised 503 as negative towards the pulse flow and 211 as supportive. The majority, 1,082, of comments raised issues unrelated to the pulse flow event. Table 4 has three examples each of posted comments categorised into supportive, negative and other.

Table 4. Examples of posted comments

Month	Posted comment	Outlet
	Supportive	
April	It's brilliant to observe just what this collaboration between the US and Mexico has achieved...	NationalGeographic.com
April	good to see this happening. there is something very wrong about using every drop of water and killing a once thriving delta.	News.yahoo.com
May	You can do an awful lot of environmental restoration with just a little water. It takes an effort but it is certainly worth it.	Azcentral.com (Arizona Republic)
	Negative	
March	We flood them with water, they flood us with illegals.	Las Vegas Review-Journal
April	...lets see, Az. Ca. in a drought and we are giving water to regrow trees in a foreign country?	News.yahoo.com
May	Wow, symbolic significance. What crap!	Arizona Daily Star
	Other	
April	By the time it gets down there it's full of chemicals and waste. They can have it.	news.yahoo.com
April	What's absurd is building a sprawling, unsustainable metropolis in the middle of one of the driest parts of the country.	Las Vegas Review-Journal
May	With the unsustainable ag era coming to an end, maybe the family farms across the rest of the nation will finally get their livelihood back?	Yahoo.news.com

The simple categorisation into positive and negative comments revealed that negative comments outnumbered positive ones on two sites (Breitbart and Yahoo) by more than 2:1. On the other sites reviewed there was a more even balance with 110 positive comments and 147 negative comments. This finding offered a contrast with the dominance of positive newspaper headlines (Table 1). The negative bias might in part be explained by the complexity of the topic that means people are less likely to join in online conversations [Hampton et al., 2014] combined with evidence that the platform of anonymity [Santana, 2014; Haines et al., 2014; Cummings et al., 2002; McKenna and Bargh, 1998; Wallace, 1999] can encourage extreme, minority views [Noelle-Neumann, 1974]. Without knowing if these are actual minority or majority opinions we caution using this type of simplistic media analysis to track the social responses to river restoration efforts.

4.3 Semi-structured interviews

The 25 in-person semi-structured interviews provided intimate, personal reflections on the pulse flow. In terms of participation, people felt drawn to the pulse flow event, to be part of something

larger; a historical event, bilateral cooperation, a celebration of hope. In describing their feelings about the pulse flow interviewees used emotive words like “pride”, “emotional”, “gratitude” and “excitement”. More nuanced comments were made by three U.S. irrigators who reminisced about swimming in the river, conceded that the pulse flow would not worsen drought but thought it was poorly timed. In response to a question about the benefits flowing from the pulse flow those interviewed talked of: restoring wetlands and wildlife; learning how to do restoration better; the immediate benefits to local people who had lived by a dry river for two generations and to the partnership between the U.S. and Mexico, and the longer-term hope that the pulse flow symbolised a new way of doing things. In terms of the timing of the pulse flow, a preponderance of those interviewed understood that spring was chosen to coincide with the germination of native trees (four named the two key species of cottonwood *Populus fremontii* and willow *Salix gooddingii*), three interviewees expressed wistfulness that it had not happened sooner, two interviewees expressed reluctance because of the drought, and four interviewees noted that the policy window for it was now or never because of wider water resources management issues in the basin. The final question about whether the pulse flow should be repeated was universally answered with a “yes” though in seven cases this was a qualified yes, if: excess water were available; the first experimental pulse flow was deemed successful; and as part of a comprehensive new Minute on water resources management in the basin.

5. Discussion

We found evidence that the process of restoration can be transformational not only for the river but also for those involved (Eden et al., 2000). Framing the pulse flow in terms of CES benefits demonstrated the importance of considering what and how different socio-hydrological drivers affect and are affected by water resource management decisions. Like many responses to water resource management decisions, changes to the water flow in the Colorado prompted debate about which values should be nourished from water flow allocations (cf. Syme and Nancarrow, 2010). The analysis of media comments showed that for some, water flowing down the Colorado was a symbol of loss of water resources and national identity that was wrapped around slurs against Mexico, Mexicans and immigrants or concerns about the flows might negatively affect their water rights. For others, restoration was a symbol of much-improved bi-national cooperation and a hope for the future of the river that had been re-imagined with flows and celebration. Still, for a large group the restoration event itself seemed to create public space to discuss other personal or ideological issues of concern to the commentator. For those interviewed their views were grounded in personal relationships to the river. The flows were a symbol of Mexican pride and hope for a new era of more balanced water resource management. Even those who we interviewed who were sceptical about the one time nature of the pulse flow and its release during a drought expressed intimate relationship to the river itself – as part of personal and family history, as advocates or as neighbours.

The dedoose content analysis of CES discussed by pulse flow phase adds insight into the temporal patterns, e.g. antecedents and reflection, as well as the dynamic nature of the social responses to the pulse flow as it evolved (S-H1) and reveals the spiritual, aesthetic, inspirational and other values associated with the river that go beyond economic values supplied by water (S-H3). It highlighted that whilst multiple codes emerged at different phases of the pulse flow the dominance

of the Activity code reflects “human services” that initiate and enable other ES flows. In the case of the pulse flow these included binational collaboration, initiating, developing and implementing an international agreement (Minute 319) and leadership by scientists and NGOs including raising money via the Raise the River campaign to support restoration efforts. Another example of human services was locals clearing litter from the dry river bed ensuring that media coverage would not be preoccupied by photos/video of floating litter. These activities built on prior river restoration science, NGO vision, local and political support and improved cooperation between the U.S. and Mexico.

Media coverage not only highlighted Activity-related human services but also CES that are often defined within certain social and cultural constructs. Many people in local communities celebrated the river values that had been reborn. In particular this newly watered landscape empowered values related to inspiration, existence, and identity. Interviewees discussed their emotional connection with the river and their hopes for future cooperation and pulse flows. For the time the river flowed it shifted day-to-day life; Jorge Figueroa, a water policy analyst with Western Resource Advocates, reported how gatherings of people underneath the highway bridge that spans the Colorado River west of the city of San Luis Río Colorado in Mexico (Fig. 3) displaced what had become the dominant use of the dry river-scape:

“There is an area close to the federal bridge that was used as an after-hours hangout, where people would go to race their bikes and jeeps, drink, and use illegal substances. The river has reclaimed and literally flushed all of that out of this site and the community wants to keep it this way. There has been …an explosion of vibrant life, of the wonder and promise of life.”

The consensus between the comments made by the attendees at the pulse flow ceremony and the comments posted on websites about the future pulse flows is striking. Interestingly supporters and opponents sometimes cited the same reasons for their positions: that without additional flows, this pulse flow would be a futile attempt at restoration with no long-term benefits. This widespread belief challenged the restoration scientists, many of who were witnessing and monitoring the pulse-flow, to better articulate the longer-term benefits of the pulse flow whilst also communicating the lack of agreement on a future pulse flow (cf. Bennett, 2014).

The moment the Colorado River connected to the sea media reports celebrated the symbolism of a river reaching its goal and the multiple and complex CES that were revived with the pulse flow; the dominance of focus on the Activity code was diminished (Fig. 5). Many of these revived CES were local, personal, aesthetic and spiritual. Historical relationships between local tribes and communities and the river ecosystems were revived and local stakeholders reported an aspiration that the river might flow again and again. The coding exercise also revealed that the less tangible CES that relate to sense of place (the main border town is called San Luis Río (River) Colorado and the indigenous community in the U.S., the Cocopah, and in Mexico the Cucapá, both mean “the River People”), to existence, identity, inspiration and spiritual reverence and wonder were prominently expressed during the final phases of the pulse flow when locals and the wider community, including journalists and bloggers, were interacting with, or witnessing, the reborn river that had finally reconnected with the sea.

The effect of water on human wellbeing (S-H2) could also be monitored through interviews and observation, of water chasers, ceremony and of spontaneous parties which captured a context rich snapshot of responses. The water chasers, the people who chased this environmental flow – environmental NGOs and government agency personnel, international dignitaries, local residents, scientists and media commentators – engaged in an ecosystem servicing process that emerges from interaction and dialogue between different people, networks and communities and their waterscape. Individual and collective response to the pulse flow integrated scientific information, values and practical considerations which highlighted the extent of the network of engaged individuals and communities who hold a personal or professional stake in the Colorado. Many of those interviewed were excited and proud to be personally involved in the flow or to witness the flow and commented on what it meant for binational collaboration and a new relationship between humans and the river. Others were concerned about the impact on their own water rights, on the third party impacts and on the futility of the event during a drought. In contrast, typical measures of human wellbeing, of Employment and Material benefits from the delta ecosystem were infrequently mentioned. This might be because the flow was small, one-off and therefore unlikely to harm or benefit the long-term economic outlook of the region, or because the other features of wellbeing, e.g. sense of place, inspiration, social cohesion, dominated.

The third goal of socio-hydrology is to understand the value of water culturally, politically and economically (S-H3) yet water values can be difficult to measure and compare [Harder et al., 2014; Seidl and Stauffacher, 2013]. Prior to the pulse flow the dominant use of Mexico's water allocation was for irrigated agricultural production; there were no instream (river) flows, flows that have been shown to have value [Collins et al., 2005; Tapsuwan et al., 2015]. This does not mean water was absent from the landscape: the entire flow of the river was diverted at the Morelos Dam through irrigation canals that are off limits to the public for safety reasons. Two key aspects of the cultural values captured in the media and in-person interviews, were embedded in the nature of the river-scape as a public space with free access and shared use. In the ecosystem service literature, access and shared use correspond to the non-excludability and non-rival features of ecosystem services (ES) [Costanza, 2008]. Whilst non-excludability and non-rivalry in use are features that can explain overuse and underinvestment in ecosystems, these same features were central to the water chaser and to local community engagement with the pulse flow, with ecosystem restoration. Access and shared use allowed the expression of multiple social and cultural values related to the river that had been dormant for decades. The experimental and opportunistic "water chasing" approach used in this study is an example of how to track and monitor ecosystem-ecosystem service relationships and water interactions with human systems [Sivapalan et al., 2014]. The insights gained we believe demonstrate the benefits of incorporating a planned socio-hydrology monitoring component into such restoration events. While interim biophysical and ecological monitoring shows that: 1) most of the pulse flow water infiltrated into the groundwater within the first 60 km downstream of its release and nearby water tables rose quickly then returned to previous levels within weeks; and 2) remotely-sensed data documented a significant increase in riparian zone greenness during the first summer, and native vegetation became established, especially in areas that were groomed for restoration [Flessa et al., 2014]. This monitoring is essential to develop a hydrologic model for the delta. Moreover, there is opportunity to co-develop socio-hydrological monitoring and modelling and to integrate such activities in the planning stages of the follow-on to Minute 319.

Further research is needed to develop metrics that expose the range of CES that enable and respond to environmental change and/or environmental policy decision-making. In the interim to such metrics being developed the perspectives gained in this paper can inform the metric design. For example the knowledge CES could be used to track knowledge sharing and building efforts to provide an indicator of the adaptive capacity of water managers to manage the uncertainty related to data quality and availability. Surveys, polls and tracking of newspaper (and other media) reporting help reveal the previous or current conflicts between stakeholders and between different priorities at different scales that need to be acknowledged and negotiated to encourage buy-in and ownership of a management plan. On-ground interviews add depth and can help expose the underlying issues surrounding the conflict, consensus and ethics of restoring ES (Jax et al., 2013). We found that these methods could also identify the identity, inspiration, heritage, spiritual and aspiration sub-categories of CES that can be used to understand and harness the diversity of stakeholder value systems required when water decisions need to apply a multi-objective ecosystem management approach. However, the methods used in this study assume that the event captures media attention and thus has a larger audience than the typical agency and funder report [Kondolf et al., 2007]. Where this is not the case, or where socio-hydrology monitoring is explicitly incorporated into the monitoring programme, methods might include surveys and focus groups on both sides of the border and with the wider public in each nation, and perhaps analysis of donations, i.e. like those to the Raise the River campaign.

6. Conclusions

This paper adopts the dimensions of socio-hydrology as a basis to understand the ES and social categories of benefits observed during a freshwater restoration event. In summary we found that access to multiple data sources – media articles, posted comments and in-person interviews over time – added richness to this preliminary analysis about the nature of support for, and opposition to this environmental flow. Diverse and contested social values in response to this environmental change were expressed through multiple pathways within the political and water planning arena and through media, celebration, and participation and reveal a multi-scalar social network that negotiated, watched, researched, protested, celebrated and bathed in this pulse flow.

Socio-hydrologic monitoring is particularly important in river basins that are managed through decision-making arrangements which enable a large number of stakeholders to contribute to the overall management of the water resource (Margerum and Robinson 2014). Monitoring social response to river condition, flow allocations and management decisions can enable these multiple stakeholders to identify the key drivers that affect the social-ecological dynamics of the river system, particularly during periods of rapid change and reorganisation – such as a drought, flood or a restoration event. As Pahl-Wostl et al., (2007) emphasise, feedbacks about the state and trends of social-hydrological interactions can also build social learning about how to best manage a river system that is appropriate to the social, political, cultural and hydrological context in which water resource management decisions are made. In this context we found posted comments provided a pathway for feedback about restoration and debate in terms of which nation, and what uses (i.e. public, private, environment, irrigation) had the right to the water of the Colorado River and by extension which groups would benefit.

The Colorado pulse flow re-created a river-scape and became a place to gather, recreate, remember and hope. Whilst the pulse flow was temporary its lasting impact may be that it introduced a generation of locals and water chasers to the lower Colorado as a river rather than as a memory. Minute 319 transformed the Colorado River for two months in spring 2014 and the ramifications cannot be undone. There is renewed vigour to chase more water for future pulse flows and there are clear audiences, i.e. the public, NGO donors, the irrigator community, government agency and policy personnel, to persuade to garner political support on both sides of the border and in turn for water managers to fully monitor future restoration efforts.

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