QUANTIFYING AND MANAGING WATER WITHDRAWALS IN THE YELLOWSTONE RIVER BASIN: INCREASING THE SCIENTIFIC RIGOR

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ABSTRACT

A scientifically-defensible system for accurate and precise quantification of existing water withdrawals and uses within the Yellowstone River Basin is necessary for effective water management. In conjunction with a data inventory of all known consumptive withdrawals from the Yellowstone River and its tributaries during the period 2006-2008, (municipal, industrial, irrigation agriculture and livestock sources), we conducted a physical inventory of surface withdrawals in 2006 to estimate the number of mainstem surface water users. Of the 687 identified water withdrawal sites, 113 were found to have screening devices present, 120 had no screens, and the screening status of 454 sites could not be determined. Ninety-two of the 687 water withdrawal sites identified during the physical inventory were not found to match with locations on the Department of Natural Resources and Conservation (DNRC) points of use or points of diversion. The lack of measured water withdrawals by most water users in the basin forces investigators to rely on indirect estimates of water use, which are inaccurate and propagate error through water use statistics. To improve the scientific credibility of data regarding the water withdrawals and improve conditions for native fish and other aquatic species, several suggestions are forwarded, including the need to screen all diversions, the need for an identification system to enable a withdrawal site to be specifically linked to a water right and the need for an accurate and precise system for measuring and reporting water withdrawals. Other identified needs are to complete the adjudication process in the state, to review the scientific evidence in support of the differential water use hierarchy in the Yellowstone River Basin, and to review terminology to eliminate, to the extent possible, ambiguous or imprecisely defined terms used in water usage. Short term benefits of applying more scientific rigor to the usage of water rights and the water management process will pay long-term dividends of more justifiable quantification of withdrawals, more reliable allocation of water, reduced litigation, and more effective conservation of native aquatic resources in the basin.

Key words: irrigation,water rights, instream flows, Montana

INTRODUCTION

"Today, not only irrigable lands cry for water, but also rivers, streams and the fish that inhabit them. New demands to serve the Northwest's growing population compete with instream needs for what little unallocated water remains." (Russell 1997, page 152)

As water demands have increased throughout the arid west in the past century, allocation and over-allocation of the limited supply have become potential sources of conflict. A few of the numerous and widespread examples include water allotment disagreements among states in the Colorado River Basin (Gelt 1997), out of basin water transfers to California that have dewatered the Owens River Valley

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(ICWD 2008), Klamath River disputes in southern Oregon and California over dams, declining fish populations, and failing water quality (Klamath 2009), and litigation between the State of Wyoming and Montana over provisions of the Yellowstone River Compact (Dengler 2007). In 2005, the Montana Legislature passed House Bill 22 (HB22) to accelerate the pace of water right claims examination and issuance of water right decrees and is requiring that all Montana water users share in the cost of completing the adjudication of Montana water rights by 2020 (Montana House Bill 22, 2005).

Water demand often is measured by amounts of withdrawal, i.e., water removal from ground- or surface water sources (Vickers 2001). Nearly all water withdrawals in the west are used for human economic activity. In aggregate, agricultural, industrial, municipal, and thermoelectric power water uses account for about 95% of all water withdrawals in the United States, although not all such withdrawals are considered consumptive, i.e. not immediately available for reuse (Kenny et al. 2009).

With the increasing demand for scarce water and recent and current basin-wide adjudications across the western U. S., many states are working to develop more accurate and precise requirements of users for reporting water withdrawals to help in their ongoing adjudications (Perramond 2012). In most localities, limited or lack of actual measurement of withdrawals has led to inaccurate estimates of historic and current usage, prolonging efforts to reach final adjudications (e.g., Washington: Bonkowski 2012; New Mexico: Perramond 2012). Inaccurately quantified withdrawals have crippled some states' ability to validate water demands in litigation. This problem was well illustrated in New Mexico v. Colorado (467 U.S. 310 (1984)) and further reinforced in the 2008 case between Montana and Wyoming (O'Regan and Shertzer 2011), when the Court required that the states have clear and convincing evidence standards to prove their case when seeking to enjoin the activities in one state that may negatively affect activities in another state. Some states that have experienced this problem have consequently enacted measures to more accurately quantify water usage (Perramond 2012).

In Montana, about 96.5% of all water withdrawals are for agriculture (Kenny et al. 2009). However, as in many locations nationwide, there is no uniform, formal, comprehensive metered approach for accurately and precisely documenting and monitoring total withdrawals. In the Yellowstone Basin, twenty-first century increases in water use demands (Cardwell et al. 1996; CFRBTF 2008) and the need for providing instream flows for the endangered pallid sturgeon (*Scaphirhynchus albus*), paddlefish (*Polyodon spathula*; Crance 1985; Firehammer and Scarnecchia 2007; Scarnecchia et al. 2009), other sensitive fish species (U. S. Army Corps of Engineers and Yellowstone River Conservation District Council 2015) and other aquatic life (Haddix et al. 1976; Penkal 1981; Proboszcz et al. 2003), have made it clear that the increasingly scarce water will need to be accounted for and conserved. Among the many western river basins dealing with water management issues, the relation between water issues and native fishes is particularly important for the Yellowstone. As the longest river in the United States that still retains a hydrograph close to natural, at least relative to other rivers of comparable size (White and Bramblett 1993), it remains a repository for many native species badly depleted or extirpated elsewhere in the broader Missouri River Basin (e.g. flathead chubs (*Platygobio gracilis*), sturgeon chubs (*Macrhybopsis gelida*), sicklefin chub (*Macrhybopsis meeki*), western silvery minnow (*Hybognathus argyritis*), Welker and Scarnecchia 2004, Scarnecchia et. al 2000; paddlefish (Scarnecchia et al. 2007), shovelnose sturgeon (*Scaphirhynchus platorynchus*); Everett et al. 2003; pallid sturgeon (*Scaphirhynchus albus*); Bramblett and White 2001; and the blue sucker (*Cycleptus elongatus*; Fig. 1). The pallid sturgeon has been listed as a federally

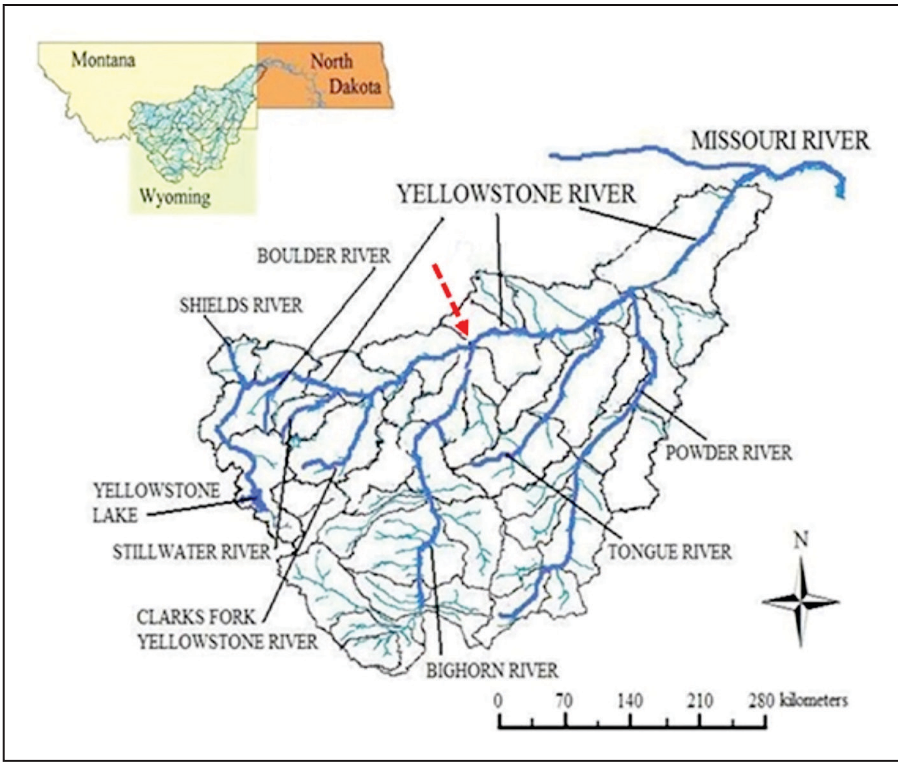

Figure 1. Montana, North Dakota, and Wyoming Map with Yellowstone River Basin Overlain. The dotted red arrow at the mouth of the Bighorn River shows where instream flow priority changes. Instream flows are second priority (behind municipal) westward, and third priority (behind municipal and agricultural) eastward.

endangered species since 1990 (U. S. Fish and Wildlife Service 2014). With so many human activities dependent upon the limited water resources and a wide array of demands on the water, increasing effort must be directed toward reconciling and planning the needs of various stakeholders and the needs for water withdrawal in relation to its retention in the river for the native biota. Compared to a century ago, there is today a wider array of legitimate demands recognized for water. As MacIntyre (1994) put it two decades ago: "Today, the west is settled… The challenge faced today in states such as Montana is to administer a limited resource for the benefit of all of the people of the state through more efficient water resource management" (p. 309).

Although many water use decisions are values-driven through the socioeconomic and political process, a major problem crippling effective water use management has been inadequate application of scientific knowledge toward it from various disciplines. A key aspect of this application involves accurate and precise measurement of defined quantities of water used for various applications. Decisions can then be made based, in part, on accurate and precise scientific data.

In the Yellowstone River Basin, an important first step is to inventory water withdrawals from the basin. In response to that need, a study was initiated in 2008 to : 1) inventory and quantify all current (2008) water rights for the Yellowstone River and its tributaries, including all state permitted water rights, all federal reserved and appropriated water rights and all other water reservations held on the rivers, 2) evaluate trends in irrigated agriculture development in the basin, 3) inventory and quantify all known consumptive withdrawals from the Yellowstone River and its tributaries in 2006 using information from municipal, industrial, irrigation agriculture and livestock sources and 4) to conduct a physical inventory of water withdrawal sites along the mainstem and major tributaries. A key result of that completed study (Watson 2014) was the documentation of widely differing levels of measuring and reporting of water withdrawals, depending strongly on the category of withdrawals. Some categories of withdrawals were measured with accuracy and precision directly with meters (e.g., municipal and industrial withdrawals), making quantification relatively simple. Other categories of withdrawals were not measured, relying instead on indirect methods of estimation, making overall assessment of water usage difficult. In the absence of measurements and evaluations, the resulting withdrawal estimates are more prone to inaccuracies and unrecognized propagation of error (*sensu* Ku 1966) in the derived statistics.

To address this concern, our approach in this study was to focus on the fourth objective above, i.e., a physical inventory of water withdrawal sites along the mainstem and major tributaries. By starting at the source, i.e., the withdrawals, in relation to results of other estimation methods reported in Watson (2014), it will be possible to make specific recommendations regarding how water withdrawal information from the Yellowstone River and its tributaries can be scientifically quantified and improved, as well as made more legally defensible, in allocating limited water resources and in water law decisions.

Methods

To estimate the number of annual surface water withdrawal sites from the Yellowstone River and its major tributaries, whether documented or not, T. Watson and field assistants boated the Montana sections of the river and the seven major tributaries (Fig.1) from source to mouth and recorded all potential surface water withdrawals (e.g., any development and equipment to aid in water withdrawals). We scheduled the individual river inventories balancing their estimated peak irrigation season and safe water levels for boating in 2009 (Table 1). Potential water withdrawal sites were recorded if there was an active withdrawal or any of the following: reasonable access to the river with equipment or evidence of use nearby, fuel or electrical means within sight from the shore, evidence of stream alteration for stilling pool to withdrawal from, any man-made division of water from the channel, or if there was irrigation equipment (pumps, piping, fuel tanks, electrical hubs) present. For each potential withdrawal site photographs were taken, UTM coordinates were logged, on-site data collection was conducted on withdrawal type (diversion or pump), estimated diameter of headgate or mainline (small: 2.5-7.6 cm; medium: 7.7-20.3 cm; or large: >20.3 cm, including all diversions), energy source (electric or fuel) and pump type (centrifugal or turbine) and observations were made to determine any evidence of recent use, and whether there was any screening device present. Screening determination was presence or absence if clearly observed, there was no further evaluation about whether the screens could adequately prevent impingement or entrainment of all life stages of native fish. All field activities were conducted while staying below the visible high-water mark. Data collected and photos taken were then mapped using ArcGIS.

Table 1. Priority of rivers based on safe flows and irrigation demand.

River	Priority	Date
Clarks Fork Yellowstone	4	June 24 – 26
Shields	1	June 30 – July 4
Powder	3	July 6 – 9
Tongue	5	July 10 – 14
Boulder	2	July 17 – 20
Yellowstone	7,8,10	July 22 – 31
Stillwater	6	August 5 – 10
Bighorn	9	Aug. 29 – Sept. 3

Municipal and industrial withdrawal sites, in contrast to most irrigation withdrawal sites along the rivers, measure withdrawals; and those data were available to the authors from the municipalities. As a measure of municipal and industrial withdrawals, we obtained the 2006 water use data from each municipality and industrial water user in the basin. These measurements were obtained from recordings at their established measurement sites.

Results

During the physical inventory, 687 water withdrawal sites were identified and locations recorded. The Yellowstone River mainstem had the most withdrawal sites (317), followed by the Tongue River (144; Table 2). Each site varied widely from zero to five pumps present or large irrigation canals.

Table 2. Withdrawal sites in the Yellowstone River Basin Montana, 2009.

River	Number of Sites	Out of State Sites
Shields	20	NA
Boulder	20	NA
Stillwater	80	NA
Clarks Fork Yellowstone	35	NA
Bighorn	27	NA
Tongue	144	NA
Powder	44	NA
Yellowstone	317	23 ND
Total	687	23

The main types of water withdrawal methods used were centrifugal pumps, turbine pumps, domestic pumps (Fig. 2), irrigation canals without diversions, irrigation canals with partial river diversions, and irrigation canals with full river low-head diversions (Fig. 3). Sizes of intake pipes and headgate entrances ranged from less than 3 centimeters (approx.1 in) to 60cm (24 in) diameter mainlines to multiple 200 cm (78 in) headgates.

Of the 687 identified water withdrawal sites, 113 were found to have screening devices, present, 120 did not have screening devices, and 454 that could not be determined. Of greater interest, there were 100 irrigation canal withdrawal sites found in the basin and only 8 of them were screened. Identifying presence of screening devices could only be done for shallow water withdrawals, unused pumps on the banks and the open canal irrigation methods at the point of diversion.

Ninety-two of the 687 identified water withdrawal sites discovered during the physical inventory were not found to match with locations on the Department of Natural Resources and Conservation (DNRC) Water Right Query System for points of use or diversion. Of these, 54% had mainline diameters greater than 10cm (4 inches), were complete and established, and showed evidence of recent use. It must be noted, however, that 45 of the 92 undocumented withdrawals sites occurred on the Tongue River, where the DNRC's Tongue River Reservoir project holds water rights for use downstream. Therefore, an unknown percentage of these sites are probably legal

Figure 2. Examples of domestic, centrifugal, and turbine pumps.

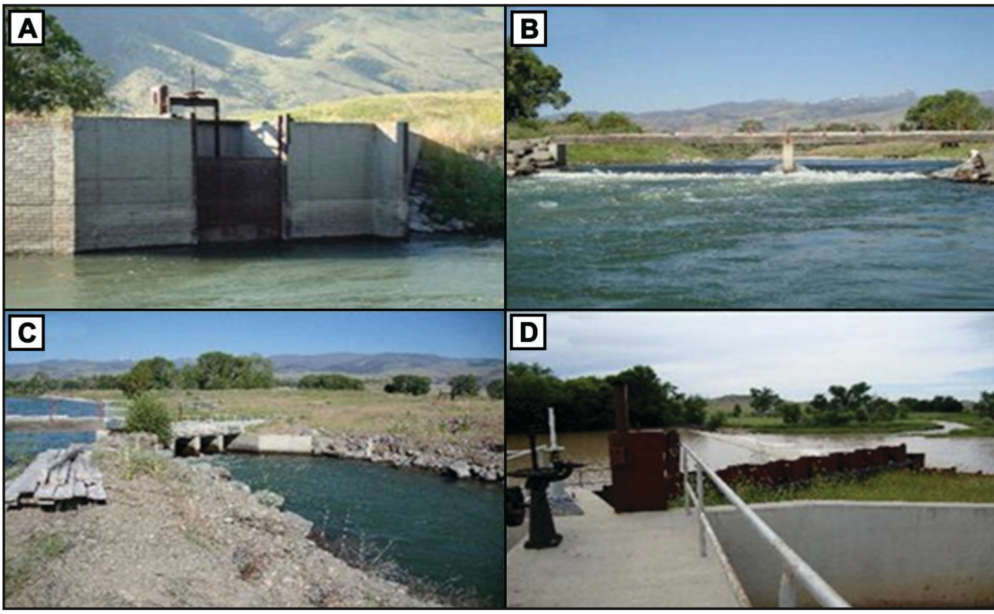

Figure 3. Examples of diversion types in the Yellowstone River Basin (A. Headgate without diversion; B. Side channel diversion; C. Multiple headgate partial channel diversion; D. Entire channel diversion with multiple headgates).

even though they do not have a water right at the point of diversion corresponding directly to them.

DISCUSSION

The results of the physical inventory highlighted some relevant scientific issues that deserve prompt attention. One major issue was lack of screening at greater than 90% of open canals diversions. Only 16 percent of the withdrawal sites (pump and canal) identified in the study were clearly screened. Although lack of screening was seldom considered important from an ecological standpoint a century ago, a large body of scientific evidence attests to the importance of screening irrigation diversions to protect aquatic life (Moyle and Israel 2005; King and O'Connor 2007; Gale et al. 2008). Lack of screening devices is of major concern in areas inhabited by species listed as endangered, threatened or of concern (Hiebert et al. 2000). Fish losses due to entrainment into irrigation devices can be substantial. Seechrist and Zehfuss (2010) found more than 6,000 fishes of 13 species entrained at the Fort Shaw diversion of the Sun River, Montana in 2003 and 2004. Heiner and Wagner (2016) reported on long term problems with entrainment of fishes at the St. Mary Diversion Dam on the Milk River, Montana. At larger withdrawal sites, entrained fishes can number into the hundreds of thousands, as estimated at Intake Diversion Canal, one of the larger irrigation canals, on the Yellowstone River (Hiebert et al. 2000). Screening of all diversions from the river, even small pump intakes, should therefore be a high priority, along with evaluation of the screening for effectiveness (Moyle and Israel 2005)

A second major issue arising from the field survey was the inability to link an actual water withdrawal with a specific water right. We were unable to match 14 percent of observed withdrawals with a water right, based on the withdrawal location in DNRC records. Under these conditions, it is often difficult to verify the legality of a pump site or withdrawal. Even if enforcement becomes an issue, which is seldom the case unless neighboring water users make a report, the water right system is confusing. When one tries to validate a claim by querying it on a map, water rights records are ambiguous in how much is available for use (Watson 2014). A more reliable approach can be found to address this issue. First, the points of diversion need to be updated on the water rights. It might also be required for the site to be geolocated at the place of diversion and place of withdrawal. Concurrently, it would be beneficial to require that water appropriators clearly mark their withdrawal site with a water right identification linking back to the specific water right on any diversion structure or pump at the point of withdrawal. These approaches will permit easier enforcement of existing water laws and be a large step toward insuring legal use by water right holders, including instream users (Poff et al. 1997), and preventing illegal use by those without water rights.

A third issue emanating from the field survey and data base inventory is the recognition that there is not an adequate system for scientifically measuring and reporting water withdrawals associated with existing water rights. Accuracy of results from our inventory were far less than optimal because accurate estimates of irrigation use from metering are not required in Montana. Instead, water use can be reported in several different, approximate ways, including estimates of time water was withdrawn, estimates and calculations built with estimates on pump and canal capacities and daily averages. The state of Montana has the legal authority to make water users measure and report water use (MCA 85-2-113(2)(a)-(c)). The problem is one of ineffective use of that authority to require accurate and precise reporting.

Under these data limitations, efforts to identify trends in irrigation water usage in Watson (2014) were based on two indirect methods, involving many questionable assumptions designed to provide both high and low-end estimates. For example, lacking accurately measured water use data, Watson (2014) used agriculture census information for Montana and Wyoming by county within the Yellowstone River Basin to estimate total area of irrigated crops. He then used two methods to estimate the amount of water appropriated for irrigation for the 2006 growing season. The two methods were 1) the Irrigation Water Requirements (IWR) program, a minimum water requirement estimate for crop type based on evapotranspiration and 2) Montana DNRC's allowed water use, for new water rights, per irrigated hectare (i.e., the maximum water amount allowed per acre based on new water right standards). These cumbersome methods were in sharp contrast to directly acquiring measured water use estimates for municipal and industrial uses (Table 3).

A complicating factor in measuring water withdrawals and documenting their legality is that in our inventory, numerous water rights proved to be lacking in pertinent information when it came to amount of withdrawals, time of withdrawals and total amount of water used by the permitted water user. On many of these rights, there were no

Table 3. Annual Industrial and Municipal water withdrawals from the mainstem Yellowstone River for 2006.

Industrial	**Withdrawn (m^3)**	**Reserved (m^3)**	**Percent Withdrawn**
YRB	525,898,955	n/a	n/a
Municipal			
Laurel	2,744,957	8,820,629	31%
Billings	34,414,276	65,991,278	52%
Miles City	1,889,261	3,563,529	53%
Glendive	1,121,614	4,047,054	28%
Total (Municipal)	40,170,108	82,422,490	49%

dates of use specified, only maximum rates of withdrawal rather than total withdrawals. Water could therefore be withdrawn at some sites at that rate for the entire year. Also, some rights had time of use but did not list restrictions on rate or quantity of water used. Unlike municipal and industrial users with water rights, many other users simply did not provide the pertinent information to properly manage any restrictions on the water use.

Overall, improvements in these areas, i.e., screening, matching of withdrawal stations to existing water rights, and metering, will go far to put Montana's water withdrawals on a more scientifically- and legally-defensible basis. Although accurate water measurement and reporting are the most fundamental tools in water management, an identified challenge had been to find a way to minimize upfront costs of meters to those with water rights. Montana addressed this in 1991 with their Water Measurement Program awarding grants to offset the costs, so metering could have been implemented at least two decades ago. A step forward in scientifically defensible and egalitarian water reporting would be to make accurate, measured reporting mandatory for all water rights.

There are many benefits to improved reporting. In litigation, courts have favored states that have claims that are quantified and recorded and have made efforts to minimize wastes. Accurate reporting not only serves to assure the courts that the water is well monitored in the state, but it also demonstrates that a state recognizes the importance and value of the water, a finite resource, to its people. This rationale is well illustrated in New Mexico v. Colorado (467 U.S. 310 (1984)), where the court required that the states have clear and convincing evidence standards to prove their side of the case when seeking to enjoin the activities in one state that may negatively affect activities in another. In a situation where a downstream state tries to enjoin the activities of an upstream state because they are being harmed, or that the downstream state believes they are not receiving their fair share of water, for either of the states to present a strong case they would have to have their rights accurately and precisely quantified. It is nearly impossible for a state to prove by clear and convincing evidence that they have the right to the water and they are not short on supply due to their own inefficiencies without accurate and defensible water data.

Watson (2014) also discussed other areas where more scientific rigor would benefit water management in Montana. One area was the need to complete the adjudication process in the state, i.e., the legal process to determine who has a valid water right, how much water can be used, and who has priority during shortages (MacIntyre 1988). The scientific implication is that without Montana's water adjudication finalized, providing maximum volumes and rates per right, there is not an accurate estimate of the total water used and available for use. In Montana, the Confederated Salish and Kootenai Tribes (CSKT) -Montana Compact and other adjudication efforts stand to benefit from more accurate and reliable data.

A second identified need was for a review of the scientific evidence in support of the differential water use hierarchy in the Yellowstone River Basin. Although this is a value-laden process, scientific information should be considered. In the upper basin, i.e. above the confluence with the Bighorn River, municipal reservations have first priority, instream use has second priority, and agriculture has third priority. In contrast, in the lower basin, i.e. below the confluence with the Bighorn River to the North Dakota border, municipal has first priority, agriculture has second priority, and instream flow has third priority (Sobashinski and Lozovoy 1982). Ecological effects of this difference could be substantial. During a low water year when the instream flow reservation is all that is available in the river, a municipality with the same water right date (1978) could use some of the instream flow reservation water to fulfill its entitlement above the Bighorn River. Below the Bighorn River, however, both reserved municipalities and irrigation operations can withdrawal from the river preferentially over the allocation for fish and aquatic life, potentially rendering the instream fish and wildlife allocation irrelevant and draining the river.

The differential prioritization of reservation usage between the upper and lower portions of the basin is a clear manifestation that instream values for native fishes have historically not been of primary concern. Although it might be argued by some that the blue-ribbon trout fisheries of the upper basin (Kerkvliet et al. 2002) are more economically important than the cool and warmwater species of the lower basin, the more diverse and more ecologically specialized native fish community of the lower basin, where more private lands exist and agriculture is more dominant, is more imperiled yet of lower priority in water allocation decisions. In recent decades, the recognition of the scientific importance of native biotic diversity has also increased the profile of the native fauna of the lower Yellowstone River (Werdon 1992; White and Bramblett 1993; Scarnecchia et al. 2008; Everett et al. 2004; Welker and Scarnecchia 2004). An important, nationally recognized fishery for paddlefish (*Polyodon spathula*) has also developed (Scarnecchia et al. 2008). As many native Missouri River species have declined, the importance of the lower Yellowstone River as high-quality fish habitat for species survival has become recognized. In terms of ecological significance, it is now understood that the river is a unified and an equally valuable resource from source to mouth, and that maintaining a natural flow regime in this and other rivers is critical to survival of many native fish species (Poff 1997; Xenopolis et al. 2006; Poff and Zimmerman. 2010).

A third area in need of more rigor identified by Watson (2014) is terminology used in water policies. Ambiguous or imprecisely defined terms continue to need clarification and where possible, quantification, as has been pointed out in past decades (Stone 1993; MacIntyre 1994). Terms such as salvaged water, beneficial use, duty of water, point of use, and waste would benefit from additional consideration and specifications in any new water management plans.

Ultimately, it is in all water users' best interests to make sure that the latest scientific methods and data collection and monitoring approaches are being used in Yellowstone River water management, and that the water withdrawals are accurately monitored and recorded. Short term benefits of applying more scientific rigor to the water management process will pay long term dividends of more defensible quantification of withdrawals, more effective allocation of water, reduced litigation, and more effective conservation of native aquatic resources in the basin.

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