

1           **Upper Verde River: Review of Stream-Riparian Monitoring**  
2           **Efforts Conducted by the U.S. Forest Service Rocky Mountain**  
3                           **Research Station**

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## Summary

The Verde River, one of Arizona's major perennial rivers, is critical for local and regional biodiversity. It provides aquatic habitat for native fish and amphibian species, including several federally listed fish species, and riparian habitat for bird species (many Neotropical migrants) and a host of other vertebrates such as river otter, beaver, and herpetofauna. Much of the Verde River corridor is managed by the USDA Forest Service. Given its ecological value and increasingly high profile, the Forest Service must have full confidence in monitoring and research data collected on the Verde River, especially data that may be used to inform management decisions. Since 1994, Rocky Mountain Research Station (RMRS) personnel have collected monitoring data on the Upper Verde River, in collaboration with the Prescott National Forest. The overall goal of this monitoring was to describe and characterize temporal changes in riparian vegetation, physical channel features, and fish assemblages in the Upper Verde River.

During the week of April 7-11, 2008, a review of RMRS research and monitoring efforts on the Upper Verde River was conducted. The review consisted of presentations, followed by field tours to different sampling locations along the Upper Verde River including portions of the river accessible only by train. Published information and data were available principally for stream flow and fish-related work. During the review, few data were available to the review team, limiting our ability to assess what RMRS has contributed to current understanding of the Upper Verde River. Preliminary results and analyses addressing interactions between vegetation, geomorphology, and fish populations were discussed. Some portion of the monitoring results will be presented in a forthcoming General Technical Report (GTR).

We interpreted the observations from monitoring efforts by RMRS researchers and colleagues on the Prescott National Forest as hypotheses, responding to them as peer reviewers, while recognizing that the interpretations have not been formally stated or tested. In addition, we provided our professional perspective on the hypotheses/interpretations with ideas on how they may be more rigorously examined.

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62 Presentations and field discussions of the monitoring data collected by RMRS  
63 personnel to date on the Upper Verde River led to concerns regarding limitations of  
64 monitoring efforts for interpreting riparian vegetation and geomorphic conditions. From an  
65 agency perspective, we believe that it is critical to emphasize that the limitations of the data  
66 must be clearly acknowledged, and that these monitoring data probably cannot be used to  
67 conclude cause-and-effect relationships or to justify management decisions. Indeed, RMRS  
68 personnel indicated that (due to lack of resources) the vegetation and geomorphic data were  
69 not collected to test hypotheses or to make cause-and-effect linkages. Until existing data are  
70 analyzed, peer-reviewed, and published, the statements and hypotheses regarding vegetative  
71 changes, trends, interactions with management activities, and linkages to fish habitat, physical  
72 characteristics and processes remain unsupported. Furthermore, lack of repeat sampling at  
73 fixed locations limits the power of the vegetation data for monitoring purposes and for  
74 evaluation of treatment effects, such as land use or natural disturbance. Despite these  
75 concerns, the collected data may be of considerable value. A recent report by The Nature  
76 Conservancy (Haney et al. 2008) notes the paucity of data available for the Upper Verde  
77 River. Following review and publication, the information derived from RMRS monitoring  
78 efforts could potentially contribute to discussions regarding future management directions by  
79 USFS and increased collaboration among the full range of Upper Verde River stakeholders.

80 **1. Introduction**

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82 The Verde River, one of Arizona’s major perennial rivers, is critical for local and  
83 regional biodiversity. The Verde River corridor provides aquatic habitat for native fish and  
84 amphibian species, including several federally listed fish species (Rinne 2005), and riparian  
85 habitat for bald eagles, southwestern willow flycatchers (federally listed as endangered),  
86 yellow-billed cuckoos (proposed for listing), other Neotropical migrant bird species, and a  
87 host of vertebrates including river otter, beaver, and various herpetofauna. Historical and  
88 current pressures on the Verde River, including recreation, roads, mining, invasive species,  
89 livestock grazing, and water extraction have likely contributed to the downward trends in rare  
90 species’ populations. A recent proposal to pump and transfer water from the Big Chino  
91 aquifer — the subsurface headwaters of the Verde River — has focused attention on the both  
92 the value and vulnerability of the Verde River basin (Haney et al. 2008).

93

94 Much of the Verde River corridor is managed by the USDA Forest Service (Region  
95 3); 40 miles of the Upper Verde River (UVR) are located within the Prescott National Forest  
96 (PNF), and portions of the Middle and Lower Verde River are within the Prescott, Tonto and  
97 Coconino National Forests. Given its ecological value and increasingly high profile, the  
98 Forest Service (especially Region 3, and the Prescott and Tonto National Forests) must have  
99 full confidence in monitoring and research data collected on the Verde River, especially data  
100 that may be used to inform management decisions. Since 1994, Rocky Mountain Research  
101 Station (RMRS) personnel have collected monitoring data on the UVR in collaboration with  
102 the PNF. The overall goal of this monitoring was to describe and characterize temporal  
103 changes in riparian vegetation, physical channel features, and fish assemblages in the UVR  
104 (Table 1). A list of observations derived from these efforts was summarized in a briefing  
105 report by Mike Leonard (Staff Officer for Planning, NEPA, Wildlife, Fish and Rare Plants,  
106 PNF) (Text Box 1).

107

108 During the week of April 7-11, 2008, a review of RMRS research and monitoring  
109 efforts on the UVR was conducted. The two objectives of the review were to: (1) assess the  
110 role of RMRS research in addressing stream-riparian management issues in the Upper Verde

111 River, particularly the status of ongoing RMRS monitoring and research in providing support  
112 for science-based management, and (2) provide input and recommendations for future  
113 research efforts. Our review focused on the following questions: What has been learned about  
114 the UVR from RMRS monitoring efforts? What is known about the Upper Verde River?  
115 What are major unknowns, particularly those that can potentially be addressed through  
116 additional research and monitoring efforts?  
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## 118 **2. Description of the UVR Stream-Riparian Review**

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120 Members of the review team (with links to their individual Websites) and National  
121 Forest Systems (NFS) participants and their respective affiliations are listed in Attachments 1  
122 and 2 to this report. Below is a brief summary of activities during the review:  
123

### 124 **1) Monday, April 7, 2008. 1:00 pm to 6:00 pm. RMRS Flagstaff Lab.**

- 125  
126 a) Presentations by Mike Leonard (PNF) and Linda Jackson (District Ranger, Chino Valley  
127 Ranger District, PNF).  
128  
129 i) Using a set of maps, Leonard provided background on the geology, hydrology, ongoing  
130 monitoring efforts on the UVR by the PNF, and land use of the Verde River basin (with  
131 emphasis on the UVR), noting the urban development patterns in Yavapai County. He  
132 also described a current proposal to pump and transport groundwater from the Big Chino  
133 aquifer to users in the towns of Prescott, Prescott Valley, and Chino Valley.  
134  
135 ii) Jackson described management issues and challenges faced by the PNF, and expressed the  
136 need for defensible information on the natural functioning of the river system to support  
137 management activities that are relevant and appropriate for the Verde River. She noted  
138 that aspects of current management are based on assumptions, and expressed frustration  
139 with application of some aspects of the ‘trout model or paradigm’, which was derived  
140 from work conducted in cold-water streams of the Rocky Mountains and Pacific  
141 Northwest, and does not reflect the natural processes of arid-land rivers.  
142  
143 b) Presentations by RMRS personnel.  
144  
145 i) Daniel Neary showed UVR hydrographs (Paulden gauge, 1963-2007) and discussed  
146 hydrologic connections between the Big Chino aquifer and Verde River surface flows;  
147 listed the types of data collected by RMRS staff on the UVR; and presented data on the  
148 soil erosion potential for uplands in the Verde River basin.

149  
150 Alvin Medina showed historic photos of the UVR; photo pairs of stream reaches before and  
151 after the 1993 floods; diagrams to illustrate riparian and geomorphic sampling methods;  
152 photos to illustrate spatial and temporal changes in stream-riparian condition in specific  
153 reaches; text slides summarizing his interpretations of changing conditions and anticipated  
154 conclusions from the 1996-2007 sampling efforts. No data were presented to support  
155 interpretations and conclusions.  
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157 2) **Tuesday, April 8, 2008. Field visits to sites along the UVR.**

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Stops were the Sullivan Dam, overlook near the confluence of Granite Creek and the UVR, Burnt Ranch (Arizona Game and Fish Dept. property), and the Verde Ranch (private in-holding on the PNF). From Burnt Ranch, we walked a portion of the river to a meadow on NFS land. During this field day, numerous topics were discussed, including: observed changes in riparian and geomorphic features prior to and following the 1993 floods; potential contributions to downward trends in native fish populations; existing information on historical conditions; natural range of variability in riparian condition and sediment dynamics; natural processes and functioning of the UVR system; management objectives, including the reinstatement of grazing on PNF riparian allotments.

169 3) **Wednesday, April 9, 2008. Verde River Canyon via Verde Canyon**  
170 **Railroad.**

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The review participants rode via train to view inaccessible portions of the river through the Verde Canyon from Clarkdale to Perkinsville and back (<http://www.verdecanyonrr.com>). This trip provided overlooks of approximately 24 miles the river, floodplain, and valley bottom, which stimulated discussions of riparian vegetation distribution, age class structure, and dynamics, tributary and upslope sediment sources, and formation and extent of geomorphic features, such as channel morphology, instream large wood, streambed materials and terraces.

179 4) **Thursday, April 10, 2008. RMRS Flagstaff Lab.**

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John Rinne presented multi-year results from fish sampling efforts on both the Gila and Verde Rivers, including: occurrence of native fish species in canyon-bound vs. alluvial-valley reaches; habitat associations of native fishes, as suggested by occurrence (presence/absence) and numbers of native species in reaches dominated by gravel, pebble, or cobble-dominated substrates; temporal changes in occurrence and numbers of fish (native and non-native); and assessment of a 3-pass method for removal of non-natives over repeated sampling years. Some of these data have been published; however, Rinne noted that considerable fish data collected on the Gila and Verde Rivers have yet to be worked up and published (includes data collected by Rinne and colleague Dennis Miller, retired from Western New Mexico University). Following his presentation, the review team returned to the Burnt Ranch site and participated in the sampling of fish along several reaches of the UVR. Using electro shocking and seining techniques, Rinne demonstrated how he and his crews sample and measure fish for both routine monitoring and non-native removal research. Upon returning from the field, the review team summarized their interpretation of the hypotheses presented by Medina, Rinne, and Neary, as derived from Powerpoint™ presentations and discussions in the field.

197 5) **Friday, April 11, 2008. 8:00 – 10:30 am. RMRS Flagstaff lab.**

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The review team worked with Neary and Medina to clarify interpretations of observations, based on Monday's presentations and discussions in the field.

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Table 1. Summary of sampling efforts by RMRS researchers on the Upper Verde River.

<b>Parameters Measured</b>	<b>Duration of Monitoring Effort</b>	<b>Status of Data</b>
<b>Hydrology</b> (Neary) Flow records from USGS Paulden gauge	1963- present	U.S. Geological Survey Open File Report 2004-1411 Neary and Rinne 1997; 2001) Rinne and Miller (2006) GTR (unpublished)
<b>Fish</b> (Rinne) Species composition	Annual sampling along 7 reaches from 1994 -2007	Rinne et al. (1998), Rinne (2005) (see additional citations in Attachment 3 ); unpublished data to be included in GTR
<b>Riparian Vegetation</b> (Medina) Herbaceous species: composition, frequency, cover  Woody species: composition, density, frequency	1997; sites 1-24 (PNF) 1998; sites 25-44 (PNF) 2000; sites on private lands 2001; sites 1-44 (PNF), sites on private lands 2002; sites on private lands 2005 – 2007; subset of sites each year	Unpublished; some portion to be included in GTR
<b>Channel Features</b> (PNF & Medina) Substrate (pebble counts), cross sections (some co-located with riparian sampling locations) slope, entrenchment, sinuosity, Rosgen channel type	1996-1998, 2000	Medina et al. (1997); unpublished data to be included in GTR
<b>Water Quality</b> (Medina) Temperature, conductivity, turbidity, suspended sediment concentration, dissolved O <sub>2</sub>	April 2000 – January 2001	Unpublished data to be included in GTR
<b>Macroinvertebrates</b> (Medina) Benthic only	2000-2001; 4 seasons, 2 habitat types (pool, riffle), 1 reach	Unpublished data to be included in GTR
<b>Historical Changes</b> (Medina) River Change Study (aerial photography analysis) Site photos River Uplands	1937-2006   1920's-present 1930's-2005	Unpublished; some portion to be included in GTR

204 Text Box 1: Observations based on monitoring efforts on the Upper Verde River by Rocky  
205 Mountain Research Station and Prescott National Forest personnel (1994-present). The list  
206 was taken from the Upper Verde River Briefing Paper, prepared by Mike Leonard, Prescott  
207 National Forest (dated March 8, 2008; Attachment 4).  
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- 210 1. The UVR is a highly impacted riverine system.
- 211
- 212 2. The primary constituent elements for spikedace and loach minnow have trended downward.  
213
- 214 3. Small bodied native fish fish species have all but disappeared, including species that are  
215 considered quite common statewide.  
216
- 217 4. Invasive fish species, Asiatic clam, crayfish and bullfrogs dominate the aquatic system.  
218
- 219 5. Flood events tend to favor native fish over non-native fish species. After large flood events in  
220 1993 and 1995, native fish species, in particular small-bodied fish such as the native daces,  
221 responded positively for one to two years, then declined rapidly. Non-native species were  
222 temporarily reduced, but regained dominance over native species within 3-4 years. Flood  
223 events of lesser sale in 2004 and 2005 did not have similar results.  
224
- 225 6. We have witnessed significant losses of sedge-dominated wetlands, important habitat for  
226 lowland leopard frogs, garter snakes and other wildlife.  
227
- 228 7. Stream bank cover from sedges/rushes has decreased.  
229
- 230 8. Woody species have increased.  
231
- 232 9. Stream channel has become narrower and deeper.  
233
- 234 10. There has been a reduction in sand and gravel substrates.  
235
- 236 11. Water quality has deteriorated (in-channel erosion of terraces, organic loading).  
237
- 238 12. Invasive plant species have increased.  
239
- 240 13. Streambank instability has increased.  
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243 **3. Management Objectives of the Prescott National Forest**

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245 Here, we briefly describe management objectives of the Prescott NF to provide  
246 background for the following sections (Sections 4 and 5) which present our perspective on  
247 how monitoring may be used to inform future management decisions. We realize that this a  
248 cursory overview of the many management challenges faced by resource specialists and line  
249 officers. During the review, PNF managers invited input on management approaches that  
250 “make sense for the Verde River”. They identified the priority management objectives in  
251 their Land and Resource Management Plan (1986) and discussed the difficulties associated  
252 with meeting the forest’s multiple uses and resolving issues of competing interests and  
253 conflicting objectives.

254

255 Elements of the plan germane to this review include:

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- 257 • **Maintain or improve fish and wildlife habitats.**
  - 258 ○ Maintain and/or improve habitat for threatened or endangered species and work
  - 259 toward the eventual recovery and delisting of species through recovery plan
  - 260 implementation.
  - 261 ○ Manage for a diverse, well distributed pattern of habitats for wildlife populations
  - 262 and fish species in cooperation with states and other agencies.
  - 263 ○ Integrate wildlife habitat management activities into all resource practices
  - 264 through intensive coordination.
  - 265
- 266 • **Restore and maintain riparian areas in satisfactory condition.**
  - 267 ○ Emphasize protection of soil, water, vegetation, wildlife and fish resources.
  - 268 ○ Give riparian-dependent resources preference over other resources.
  - 269
- 270 • **Water Quality and Quantity, Watershed Condition, and Soil Productivity**
  - 271 ○ Protect and improve the soil resource.
  - 272 ○ Provide for long-term quality water flow needs through improved management
  - 273 technology.
  - 274 ○ Restore all lands to satisfactory watershed condition to improve quantity and
  - 275 quality of water produced and distribution of flow.
  - 276
- 277 • **Range**
  - 278 ○ Meet threatened and endangered species requirements in all range or grazing
  - 279 activities.
  - 280 ○ Manage livestock grazing to achieve soil and water protection objectives.
  - 281 ○ Eliminate yearlong grazing prescriptions for riparian areas.
  - 282 ○ Implement of grazing systems that will advance ecological objectives for
  - 283 riparian-dependent resources with sufficient rest to meet physiological needs of
  - 284 vegetation.
  - 285 ○ Restrict allowable utilization of woody riparian species to  $\leq 20\%$ .
  - 286

287           The Comprehensive Management Plan for the Verde Wild and Scenic River (2004),  
288 though covering a river segment downstream and, at this time, not inclusive of the Upper  
289 Verde, provides an example of multiple objectives for river management. The Verde Wild and  
290 Scenic River Plan emphasizes native fish species over nonnative fishes; the recovery,  
291 development, and maintenance of aquatic habitat with low substrate embeddedness, abundant  
292 aquatic food supply, and stable streambanks; and, additionally, the recovery, development,  
293 and maintenance of riparian vegetation characteristics (i.e. composition, density, and height)  
294 necessary for riparian-dependent species.

295

#### 296 **4. Observations and Hypotheses Derived from RMRS Monitoring Efforts**

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298           A summary of the monitoring data collected by RMRS personnel (Table 1) was  
299 derived from Powerpoint™ presentations (April 7) and follow-up discussions. Content of the  
300 forthcoming GTR was generally discussed during the review; however, a draft copy was not  
301 provided because it was not yet ready for any level of distribution. The collection of certain  
302 data was collaborative between the PNF and RMRS, and it was unclear if the GTR will  
303 contain data collected by the PNF. Analyses of RMRS monitoring data are underway for the  
304 vegetation and geomorphic metrics. Our impression is that the UVR hydrographs and soil  
305 erosion information will also be included in the GTR. In addition, Medina has compiled an  
306 historical photographic record database to determine historical changes in the UVR.  
307 Currently, plans are to include some portion of the assessment of historical photographs in the  
308 GTR (please see Attachment 4).

309

310           During the review, the data available for discussion were essentially limited to the fish  
311 monitoring data provided by Rinne, some of which have been published (see Attachment 3 to  
312 this report). This limited our ability to address the first objective of the review: *(1) assess the*  
313 *role of RMRS research in addressing stream-riparian management issues in the Upper Verde*  
314 *River, particularly the status of ongoing RMRS monitoring and research in providing support*  
315 *for science-based management.* However, numerous observations — derived from  
316 monitoring efforts by RMRS scientists and PNF staff — on the ecological and physical  
317 processes of the UVR were presented on April 7 and discussed in the field. Therefore, the

318 review team decided to organize this report around the observations themselves, considering  
319 them as working hypotheses about how the UVR functions. We recognize that some of these  
320 observations and interpretations may change as data are analyzed in more detail, and  
321 presented in the GTR and future publications. Since the observations and interpretations are  
322 being discussed among NFS and RMRS staff and other stakeholders, we focused on providing  
323 our ‘peer-review’ perspective to each hypothesis. Below, we comment on each hypothesis  
324 and the extent of supporting data or evidence to advance the discussion regarding the ecology  
325 and management of the UVR.

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327

#### 328 ***4.1 Riparian Vegetation Hypotheses***

329

- 330 1. Woody vegetation establishment on the banks and floodplain causes channel narrowing and  
331 bed incision; incision causes lower water table and loss of wet meadows. Woody vegetation  
332 on floodplain causes scour through deflection and concentration of flow, leading to erosion  
333 and loss of meadows.  
334
- 335 2. Herbaceous-dominated meadows are stable and resistant to loss during high flow events (20-  
336 30 yr. floods under current climatic conditions); UVR lost most wet meadows sometime  
337 between 1979 and 2007.  
338
- 339 3. Increases in cover of woody species are associated with loss of wide, low gradient riffles  
340 (desirable native minnow habitat); the Verde River system did not “evolve with woody  
341 vegetation” (Medina, pers. comm.).  
342
- 343 4. Variability in vegetation species composition/cover/density is high within and among sites  
344 over space and time, and is dependent on plant community type and position on the  
345 floodplain; variability is lower on grazed, sedge-dominated communities.  
346
- 347 5. After high-flow events, grazed sites have lower cover of herbaceous invasives than ungrazed  
348 sites.  
349
- 350 6. Woody vegetation could be linked to debris jams that could precipitate a catastrophic, dam-  
351 break flood.  
352
- 353 7. Under current climatic regime (prior to 1890’s or recent settlement), woody vegetation could  
354 have been a significant component of the UVR ecosystem, but there is no evidence either way.  
355 Dating of buried wood in channel terraces may provide data.  
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361 ***Response to Riparian Vegetation Hypotheses:***  
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- 363 1. Woody vegetation establishment on the banks and floodplain causes channel  
364 narrowing and bed incision; incision causes lower water table and loss of wet  
365 meadows. Woody vegetation on floodplain causes scour through deflection and  
366 concentration of flow, leading to erosion and loss of meadows.  
367

368 Channel narrowing and incision due to encroachment of vegetation is a well known  
369 process that can result from factors such as reduced stream flows, introduction of invasive  
370 species, or exclusion of ungulate grazing (McDowell and Magilligan 1997). This process was  
371 evident along the lower reaches of the UVR upstream from Clarkdale, where nearly  
372 continuous riparian vegetation confined the river and was associated with deep, narrow  
373 channels. The encroachment in this part of the river is a recent phenomenon (Webb et al.  
374 2005). However, similar confinement by riparian vegetation and association with deep  
375 channels was not observed at other sites visited (Burnt Ranch, Verde Ranch). Consequently,  
376 further demonstration of this hypothesis is needed before it can be accepted as a general  
377 response along the UVR.  
378

379 While it is plausible that incision causes lower water tables and loss of wet meadows,  
380 no supporting evidence was provided, nor is it clear that vegetation is the primary cause for  
381 incision. Other causes for incision at the field sites visited may include loss of beaver dams,  
382 downstream changes in base level, and periodic sedimentation at tributary junctions leading to  
383 cycles of channel aggradation and subsequent headcutting (upstream incision and knickpoint  
384 propagation). Beaver activity and tributary debris fans were observed during site visits.  
385

386 Floodplain patches of woody vegetation create flow obstructions that can cause local  
387 scour upstream of the obstruction and complimentary deposition in the wake of the  
388 obstruction (e.g. Abbe and Montgomery 1996). However, the net effect of this process (scour  
389 vs. deposition) is not known, nor is it known whether the resultant scour around multiple  
390 woody obstructions would cause or contribute to the collapse of wet meadow systems.  
391

392 Channel narrowing may be facilitated by vegetation establishing adjacent to and in the  
393 channel, although vegetation establishment may also occur in response to channel narrowing

394 (Hereford 1984). Cause and effect may be difficult to determine without field data on channel  
395 dimensions through time, establishment dates and ages of woody vegetation, and a detailed  
396 look at sediment stratigraphy. Reductions in peak flows, reduced frequency of high-flow  
397 events and reduced base flows may all result in channel narrowing, even in the absence of  
398 woody vegetation. Medina et al. (1997) discuss channel incision and its many possible  
399 causes, but present no strong evidence that incision has occurred or continues to occur. If  
400 channel incision is occurring, it is likely that shallow alluvial groundwater levels have  
401 declined and that wet meadows would transition to more mesic and xeric vegetation types.  
402 Vegetation and channel morphology data collected to date may suggest trends in feedbacks  
403 between vegetation and channel and floodplain form, but cannot be used to make cause-and-  
404 effect inferences. Additional, focused research on the UVR would be required to accept or  
405 reject these hypotheses.

406

407 2. Herbaceous-dominated meadows are stable and resistant to loss during high flow  
408 events (20-30 yr flood under current climatic conditions); UVR has lost most wet  
409 meadows sometime between 1979 and 2007.

410

411 Several studies demonstrate that grasses and non-woody shrubs can armor riverbanks  
412 and floodplains when this vegetation is pushed over during floods (Nepf 1999; Simon and  
413 Collison 2002). Furthermore, vegetative roots strengthen soils and make them more resistant  
414 to erosion. However, there is a threshold beyond which discharges and boundary shear  
415 stresses exceed the resisting strength of the vegetation, causing it to be eroded or uprooted.  
416 Consequently, the stability offered by grasses and shrubs has limits. The suggested value of a  
417 20-30 year flood for this threshold is reasonable, but requires supporting documentation.  
418 Furthermore, as discussed above, it is unclear what has caused the observed loss of wet  
419 meadows in the UVR. Further consideration and analyses of competing or alternative  
420 hypotheses are needed.

421

422 Meadows dominated by perennial graminoids likely were historically transient  
423 features, as the Verde River hydrology is characterized by periodic flash-floods of large  
424 magnitude. Recent work on Sycamore Creek, AZ indicates that riverine wetlands are  
425 'alternative stable states' and their persistence is largely driven by periodic flooding  
426 (Heffernan 2008). It is difficult to say whether wet meadows are more or less abundant today

427 than they were historically and to assign reasons for changes. Photographs from the 1920s  
428 revealed a freshly scoured channel with little vegetation of any kind. RMRS personnel saw  
429 this as evidence that woody vegetation is a recent phenomenon and indicated that these  
430 interpretations were corroborated in repeat photographs in the “Ribbon of Green” (Webb et al.  
431 2005). However, the pre-photos in all cases were from the late 19<sup>th</sup> and early 20<sup>th</sup> centuries,  
432 following European settlement. Settlement involved cutting wood for both fuel and building  
433 materials and the introduction of livestock, which undoubtedly influenced woody species  
434 (Leopold 1924). The late 19<sup>th</sup> and early 20<sup>th</sup> century was also a period of unusually frequent,  
435 extreme flood events in this region (Ely et al. 1993). These photos provide a snapshot in time,  
436 not necessarily a view of stable reference conditions. Furthermore, the lack of wet meadows  
437 in the photos presented by RMRS personnel provides little evidence of extensive wet  
438 meadows prior to woody vegetation establishment. It is likely that the upper Verde River  
439 corridor has been very dynamic (rather than a stable wet-meadow dominated system) and at  
440 any point in time contained marsh, meadow, woodland, and bare channel margin in some  
441 stage of recovery from the most recent flood.

442

443 It seems difficult to generalize that grazed wet meadows are more resistant to erosion  
444 than woodlands. It depends on proximity to the channel, the composition of the vegetation;  
445 stem density; the condition of the vegetation; root morphology; sediment/substrate texture;  
446 exposure to fluvial processes; and a range of other factors that vary spatially and through  
447 time. It is not difficult to imagine a wet meadow along a cut bank eroding on one side of the  
448 channel and being stable on the opposite side of the channel during a single flood event.  
449 Without data it is difficult to evaluate the claims about meadow stability and resistance to  
450 scour. Since riparian vegetation data were gathered in plots at different locations (non-  
451 permanent plots) it is even more difficult to assess change in vegetation through time or to  
452 relate observed differences between plots to relevant variables (grazing intensity, hydrology,  
453 other land uses).

454

455 Haney et al. (2008) estimate that only 12 out of 5587 acres of riparian area along the  
456 UVR are composed of ‘wet meadow plant communities’. The estimate was based on a  
457 mapping effort by the Arizona Game and Fish Department (including private and public

458 lands) and indicates that wet meadows currently occupy a very small proportion (i.e., 0.2%)  
459 of the UVR riparian area. The narrow valley bottom throughout much of the UVR likely  
460 limits the formation of meadows (even small ones), which requires deposition and  
461 accumulation of fine sediment and some degree of soil development. Soil development  
462 occurs during the intervals between large floods and may be accompanied by wet meadow  
463 formation. Furthermore, beaver likely had an important role historically in the formation and  
464 persistence of wet meadows in southwestern rivers like the UVR (Butler and Malanson 2005).  
465 The extent of meadow loss needs to be quantified and examined spatially within a watershed  
466 context, i.e. in terms of available sites as influenced by both physical and biological  
467 processes.

468

469 Evidence for both recent and historic changes in the extent of wet meadows may  
470 contribute to improved understanding about the processes that influence the location, extent,  
471 and persistence of wet meadows in the UVR system. However, no supporting information or  
472 data were available during the review. RMRS personnel also indicated that the maintenance  
473 of wet meadows was a priority management goal for private lands on the UVR to maximize  
474 forage production for livestock. On FS lands, additional management goals include habitat  
475 diversity, recreation, and maintenance of high quality, functioning, sustainable riparian areas,  
476 some of which are in direct conflict with management on private lands that tend towards a  
477 narrow range of habitats or a single habitat type (e.g., wet meadows).

478

479 3. Increases in cover of woody species are associated with loss of wide, low gradient  
480 riffles (desirable native minnow habitat); the Verde River system did not “evolve with  
481 woody vegetation” (Medina, pers. comm.).

482

483 Early expeditions in the Verde River watershed indicate that there were meadows,  
484 riparian forest and shrublands along the river in the 1850’s (Leopold 1951; Shaw 2006).  
485 Riparian trees along the river included cottonwood, willow, ash, and walnut (Leopold 1951;  
486 Shaw 2006). These studies also indicate that “large trees were apparently harvested quickly  
487 after the Anglo arrival” (and prior to historical photographs; Shaw 2006). Hence, it is unclear  
488 whether the observed increases in riparian vegetation represent recovery to natural conditions  
489 following disturbance by settlers, or whether subsequent land use has allowed greater  
490 vegetation growth than was historically present prior to arrival by settlers (Leopold 1924).

491 If riparian vegetation is contributing to channel narrowing, it is possible that riffles  
492 and associated minnow habitat could be replaced by deeper channel morphologies (runs and  
493 pools). However, no supporting data were offered to support this hypothesis and no data-  
494 based association between the presence of woody vegetation and channel morphology was  
495 presented. During the review, RMRS personnel noted that some of the vegetation plots were  
496 co-located with permanently monumented channel cross sections. The review team suggested  
497 that the woody vegetation data, especially stem density and cover, could be analyzed in  
498 relation to the nearest permanent channel cross section to explore the above hypothesis. The  
499 method used to locate the vegetation plots, which were not permanently marked and may have  
500 changed each year depending on the stream/streambank location, may limit the types of  
501 spatial and trend analyses in vegetation that can be conducted. However, correlations  
502 between annual changes in the cross sections and woody vegetation characteristics could  
503 potentially be examined. If not part of current monitoring protocols, measurement of particle  
504 sizes in the vegetation plots is recommended to determine the substrate composition on which  
505 the woody species have established and to determine the order of events (tree  
506 establishment>sediment deposition>channel narrowing or sediment deposition>channel  
507 narrowing>tree establishment; Hereford 1984).

508  
509  
510  
511  
512

4. Variability in vegetation species composition/cover/density is high within and among sites over space and time, and is dependent on plant community type and position on floodplain; variability is lower on grazed sedge-dominated communities.

513 Riparian vegetation is known to be highly variable in both space and time (Bagstad et  
514 al. 2005; 2006; Lite et al. 2005). High interannual and intersite variability is typical of  
515 dynamic arid land riparian communities and leads to high plant diversity through time.  
516 Turnover of vegetation may be caused by natural disturbance processes such as flooding and  
517 the creation and destruction of new sites through scour and deposition (Bagstad et al. 2005;  
518 2006; Lite et al. 2005). Turnover also occurs over the course of a single season as the  
519 availability of moisture changes from temporarily abundant during spring snowmelt and  
520 monsoon rain, to scarce during dry intervening periods (Stromberg et al. 2007). The exciting  
521 challenge for riparian plant ecologists is to explore the potential explanatory factors and  
522 determine which factors account for (or explain) some proportion of the variability,  
523 recognizing that considerable information may be contained in the variability itself. During

524 the review, no vegetation data were presented, so the review team was not able to evaluate  
525 spatial or temporal variation in any of the vegetation data (composition, cover, richness,  
526 herbaceous vs. woody, exotic vs. native, etc.), although we would expect variability across  
527 plots, sites, and through time.

528

529         Considering the following questions in the data summary and analysis (in the  
530 forthcoming GTR) may assist in interpretation: how does within-site variability compare to  
531 the between-site variability both within years and across years? How much of the between-  
532 site variability (both within single years and across years) can be explained by site/reach  
533 characteristics such as valley bottom width, substrate composition, position on the floodplain,  
534 elevation, etc? How much of the between-year variability can be explained by hydrograph  
535 characteristics, precipitation, time since last flood, etc? What is the nature of the variability  
536 (i.e. species turnover, changes in cover, over what time frames)?

537

538         Limitations of the vegetation sampling methods and study design need to be  
539 acknowledged and may restrict the ability to address some of the questions presented above.  
540 First, by not permanently establishing vegetation transects or plots, the temporal variability  
541 may be more difficult to explain than if data were collected within the same plots (exact  
542 location) each year. Because the vegetation plots were located adjacent to the stream, plot  
543 locations changed at some sites from year to year (as indicated by RMRS personnel during  
544 site visits). So, although vegetation was sampled along the same reach or ‘sampling station’,  
545 the same area (plot location) may not have been sampled year-to-year. This may introduce a  
546 source of variation that might have been controlled or avoided. Given random sampling of  
547 the site and enough plots to characterize intra-site variability this might be an acceptable  
548 method, but given limited resources, permanent plots would have been advisable.

549

550         Second, because transects and plots were arranged directly adjacent to the active  
551 channel, a limited portion of the riparian area and floodplain were sampled. While these  
552 vegetation data may provide information about streamside conditions, particularly the  
553 dynamic and transient nature of the active channel, they probably do not incorporate the  
554 diversity of riparian vegetation and conditions along floodplain hydrologic gradients (i.e. the

555 sampling approach may have consistently under-sampled the riparian area). It is difficult to  
556 predict how this sampling method may have influenced variability in the data, but it is  
557 important to clarify that, due to placement of transects and plots, the data represent only the  
558 portion of the riparian area directly adjacent to the stream. Finally, the monitoring protocol  
559 used for the UVR data collection was presented to the group, but the methods used by the  
560 PNF for collection of its early monitoring data differ from those currently employed by the  
561 RMRS. Comparison of these databases should be approached with caution. The influence of  
562 changes in sampling protocols needs to be considered.

563

564 One of the ‘information needs’ identified by Haney et al. (2008) for the Verde River  
565 was ‘complete flora of the Verde River riparian corridor, ideally by river reach and for  
566 specialized habitats such as main stem spring sites’ (page 45). The publication of the GTR  
567 may address this need; authors are encouraged to explicitly indicate sampling sites/stations  
568 with linked species lists for each site, so that readers can appreciate the extent of this floristic  
569 information.

570

571 5. After high-flow events, grazed sites have lower cover of herbaceous invasives than  
572 ungrazed sites.

573

574 Although a plausible hypothesis, no supporting data were provided during the review.  
575 Since herbivory is associated with removal of biomass, it is likely that most herbaceous  
576 species, native and invasive, would have lower cover at grazed sites.

577

578 If possible, we suggest that the data obtained from vegetation sampling be aimed at  
579 addressing fundamental questions that could potentially inform management: What are the  
580 herbaceous invasive species of concern and which are palatable to livestock and likely to be  
581 selected over natives? Over what time periods were relative cover differences at grazed vs.  
582 ungrazed sites observed? What are the levels or magnitudes of difference in cover (overall  
583 and by species) between grazed vs. ungrazed sites? How analogous ecologically are grazed  
584 vs. ungrazed sites (are they ecologically similar except for the grazing management)? How  
585 do grazed vs. ungrazed sites differ in overall composition of herbaceous species? What is the  
586 relative importance of grazing and hydrologic factors in determining the abundance of native

587 and invasive plant species? Answers to the questions regarding the influence of grazing need  
588 to be supported by carefully designed studies, data analysis and objective interpretation.  
589 Evidence would come from carefully designed vegetation sampling along grazed and  
590 ungrazed reaches, replication, controlling for other factors that influence vegetation  
591 composition and cover, and statistical analysis of the data. For example, whereas the use of  
592 livestock to control weedy species is a common practice and can be used to facilitate native  
593 plant growth, overgrazing of natives can also open up space (bare or sparsely vegetated  
594 ground) providing opportunities for weedy species to invade.

595  
596 6. Woody vegetation could be linked to debris jams that could precipitate a catastrophic,  
597 dam-break flood.

598  
599 While possible, the probability and magnitude of such an event is unclear. Is there any  
600 historic evidence of dam-burst floods occurring in the UVR system, or in neighboring basins?  
601 What resources are at risk, and would the floodwave be dissipated by overbank flows?

602

603 7. Under current climatic regime (prior to 1890's or recent settlement), woody vegetation  
604 could have been a significant component of the UVR ecosystem, but there is no evidence  
605 either way. Dating of buried wood in channel terraces may provide data.

606

607 Woody vegetation has long been an important component of western arid-land riparian  
608 habitats. Woody vegetation growing along streams in the Verde River watershed (including  
609 the mainstem) were mentioned dozens of times in journals dating from the 1850's (Sitgreaves  
610 expedition in 1851 and Whipple in 1854, both referenced in Shaw 2006). Specifically  
611 cottonwood, willow, Arizona walnut, and Arizona ash are mentioned to have been growing  
612 along the banks of streams in this period prior to heavy grazing by livestock and prior to  
613 timber harvest by Anglo settlers. Wet meadows were also mentioned further suggesting that  
614 riparian areas were varied and (as we would expect) consisted of both woody and herbaceous  
615 vegetation. The relative abundance of woody vegetation likely fluctuates as a function of  
616 water availability and frequency and magnitude of fluvial disturbances, both of which are  
617 influenced by climate (cycles of snowpack- and monsoon-driven water delivery) and, water  
618 management (both surface and subsurface). The abundance of woody vegetation is also  
619 influenced by herbivory in the form of beavers, other native herbivores and livestock.  
620 *Populus* and *Salix* form a biologically important association that is often the focus of

621 management in the southwest. The occurrence of water sources (springs, shallow  
622 groundwater) and occasional disturbance are conditions consistent with the presence of well-  
623 dispersed disturbance-adapted taxa such as *Populus*, *Salix*, *Baccharis*, and a suite of other  
624 native riparian species in the Colorado Plateau and Sonoran desert. In Webb et al. (2005,  
625 page 300), annual flood series are presented for 4 stream gauging locations on the Verde  
626 River, including the Paulden gage (established 1963). Downstream gages (established in  
627 1890, 1915, and 1938) could potentially be used to extend the flood series for the upper part  
628 of the basin and assist in explaining recruitment patterns of woody vegetation.

629

630 The historic role of woody vegetation in the UVR is a critical question that deserves  
631 further investigation. Trenching or ground-penetrating RADAR might be used to document  
632 stratigraphy and to search for buried wood within river terraces. Carbon dating and  
633 dendrochronology of recovered wood could allow reconstruction beyond historical photos and  
634 written records.

635

#### 636 ***4.2 Sediment and Channel Morphology Hypotheses***

637

- 638 1. Sediment supply has been reduced by Sullivan Dam.
- 639
- 640 2. Ongoing channel incision of river terraces is a source of fine sediments; a secondary  
641 sediment source is from tributaries.
- 642 3. (“Hanging”) tributaries are adjusting to downcutting in the main stem river and are  
643 contributing sediment via knickpoint propagation (upstream headcutting).
- 644
- 645 4. Cross sections have shown that some channel reaches have incised up to 1 m between  
646 1996 and 2008 (data and photo-documentation (Black Bridge) will be in GTR);  
647 overall the entire UVR is incising.
- 648
- 649 5. Majority (80%) of UVR consists of B and C channels according to Rosgen  
650 classification (based on 1998-9 surveys); resurveys are needed to assess channel  
651 changes and trends.
- 652

653 ***Response to Sediment and Channel Morphology Hypotheses:***

654

655 1. Sediment supply has been reduced by Sullivan Dam.

656

657 Historically, sediment supply was likely reduced by the dam, but given the amount of  
658 sedimentation that has occurred upstream of the dam, it is unclear what the current trapping  
659 efficiency of the dam is, particularly for fine sediments. Furthermore, there are numerous  
660 sediment sources downstream from the dam (e.g. sparsely vegetated sideslopes, eroding  
661 terraces, tributary fans). The sites that were visited along the UVR had a broad range of  
662 particle sizes, depositional bedforms, and did not show obvious evidence of being sediment-  
663 limited. Analysis of channel characteristics collected by RMRS personnel over the sampling  
664 period may provide evidence of reduced sediment supply in terms of grain-size coarsening  
665 and/or channel incision. However, similar responses could also be caused by other processes  
666 (e.g. changes in downstream base level due to loss of beaver dams, wood jams and breaching  
667 of tributary fans, or relaxation following sediment inputs from historic floods (e.g. Madej and  
668 Ozaki 1996)). Consequently, there may be multiple, competing interpretations for observed  
669 changes in channel characteristics. Development of a sediment budget (Reid and Dunne  
670 1996) and further quantification of the geomorphic effects of the dam (Grant et al. 2003)  
671 might resolve these issues. Finally, the consequences of reduced sediment supply on the  
672 physical and biological function of the river are unclear and deserve further explanation and  
673 quantification.

674

675 2. Ongoing channel incision of river terraces is a source of fine sediments; a secondary  
676 sediment source is from tributaries.

677

678 Eroding terraces were sediment sources at some of the sites visited, as were tributaries,  
679 which showed evidence of both recent and older sediment inputs (debris fans that in some  
680 cases may have temporarily blocked or diverted the river). However, the extent of these  
681 inputs, their characteristics (grain size, volume, and rate of supply), and their biological and  
682 physical consequences remain to be quantified. Development of a sediment budget, as  
683 discussed above, would partly address these issues.

684

685 3. (“Hanging”) tributaries are adjusting to down cutting in the main stem river and are  
686 contributing sediment via knickpoint propagation (upstream headcutting).

687

688 These are plausible hypotheses, but require further evidence to be able to assess their  
689 validity. Repeated longitudinal surveys of the mainstem river and its tributaries would help to  
690 document the location, rate of movement, and concordance of knickpoints, while a sediment  
691 budget and/or bedload transport measurements would quantify the rate and size distribution of  
692 sediment inputs to the mainstem river. As discussed above, the relative physical and  
693 biological significance of these processes should be evaluated, ideally with some preliminary  
694 back-of-the-envelope calculations to assess potential significance before investing resources  
695 in further analyses of the issue.

696

697 4. Cross sections have shown that some channel reaches have incised up to 1 m between  
698 1996 and 2008 (data and photo-documentation (Black Bridge) will be in GTR); overall the  
699 entire UVR is incising.

700

701 While plausible, this observation cannot be assessed at this time since the GTR and  
702 supporting data are not available. A subset of the data published by Medina et al. (1997)  
703 show channel incision, and the authors state that 14% of the channel length is unstable.  
704 However, further documentation of the spatial extent of such change along the length of the  
705 UVR, and within the context of geomorphic process domains (unconfined alluvial reaches vs.  
706 confined segments) (Montgomery 1999; Montgomery and Buffington 1997), is needed to  
707 assess the broadscale condition of the river. Moreover, study of the underlying causes for  
708 observed channel changes is needed. For example, some of the incision presented to the  
709 group during the field review was likely caused by tributary sediment inputs and consequent  
710 cycles of mainstem aggradation and subsequent headcutting (knickpoint incision) that from  
711 our limited field reconnaissance seems to be part of the natural, long-term geomorphic  
712 function of the UVR system. Placing observed channel changes within this larger  
713 geomorphic context is needed to understand both the cause and potential spatial extent of such  
714 changes.

715

716 5. Majority (80%) of UVR consists of B and C channels according to Rosgen  
717 classification (based on 1998-9 surveys); resurveys are needed to assess channel changes  
718 and trends.

719  
720 Rosgen classification provides a basic description of channel morphology that may be  
721 a useful inventory and communication tool. However, it is unclear what, if any,  
722 interpretations will be made from these data. Using channel classification to infer  
723 stability/dynamics is cautioned. Furthermore, changes in state, both in terms of channel  
724 dimensions and overall morphology, may be part of the natural range of variability of some  
725 channels; hence, change should not be viewed as problematic until those changes are placed  
726 within the context of the natural range of system variability. Arid environments with flashy  
727 hydrographs are more likely to exhibit a broader range of channel conditions over time than  
728 snowmelt-dominated physiographies (Buffington and Parker 2005).

729

#### 730 ***4.3 Fish Hypotheses:***

731

- 732 1. Since 1994, there has been significant decline in native spp and increase in nonnative  
733 spp; relative abundances have changed from 80:20 native:nonnative to roughly the  
734 reverse. Since 1994, total number of all (native and nonnative) fishes sampled has  
735 declined as well.
- 736  
737 2. Abundance and distribution of small native fishes are associated with and benefit from  
738 the availability of, wide, shallow, low gradient habitat types. These appear to be  
739 particularly important for the small minnows, but are also used by non-native red  
740 shiners.
- 741  
742 3. Non-native fishes benefit from narrow, deep channels and associated habitat types  
743 (e.g. pools, high gradient riffles, deep runs, undercut banks).
- 744  
745 4. Native and nonnative fish community structure interacts with valley form, hydrology,  
746 and other geomorphic process.
- 747  
748 5. Predation by nonnative fishes is an important if not dominant constraint on native spp.  
749 recruitment.
- 750  
751 6. Recruitment in native species is facilitated by large floods.
- 752  
753 7. Restoration of wide shallow habitats (high width/depth ratio) would reduce non-  
754 natives and increase native spp abundance.

755

756 ***Response to Fish Hypotheses:***

757

758 1. Since 1994, there has been significant decline in native spp and increase in nonnative spp;  
759 relative abundances have changed from 80:20 native:nonnative to roughly the reverse.  
760 Since 1994, total number of all (native and nonnative) fishes sampled has declined as  
761 well.

762

763 The data show substantial differences in relative number of native and non-native  
764 species with a general trend favoring non-native species since the 1993 flood. Spikedace have  
765 disappeared from samples. The sampling maintained by the Forest Service is limited in extent  
766 and by itself could be vulnerable to systematic bias or sampling error, but more continuous  
767 sampling conducted by other agencies confirms the general pattern. The trends in the data are  
768 striking and although sampling error is not addressed, the magnitude of change is large  
769 enough to overwhelm most anticipated sampling problems. Dramatic changes in community  
770 structure favoring non-native species and a substantial decline (if not extinction) in spikedace  
771 has undoubtedly occurred since 1994. There is no way to determine the variability in  
772 abundance in native species and spikedace before 1994. The monitoring data outlined above  
773 show a substantial decline in total number of fishes (native +non-native since 1994). There  
774 has been no discussion or speculation about this pattern, but it is consistent with a decline in  
775 small bodied and short-lived native minnows and an increase in large bodied, longer lived  
776 non-native forms. There is no information to consider changes in overall fish biomass or  
777 production.

778

779 2. Abundance and distribution of small native fishes are associated with and benefit from the  
780 availability of, wide, shallow, low gradient habitat types. These appear to be particularly  
781 important for the small minnows, but are also used by non-native red shiners.

782

783 Observations during routine sampling suggest that the presence of native fishes,  
784 particularly the small minnows (spikedace; longfin dace, speckled dace) is associated with  
785 shallow, low gradient habitat types. The primary evidence are general patterns of species  
786 occurrences which include relative abundances associated with geomorphological constraints  
787 (e.g. canyon bound vs. alluvial valleys) and relative abundance or capture rates among habitat  
788 types (e.g. high and low gradient riffles, glide runs, pools, etc). Fish are caught in greater  
789 abundance, or only, in these habitat types. A decline in abundance of small native minnows  
790 has also occurred concurrently with apparent channel narrowing and deepening. Channel

791 measurements presented to date are limited to two sites and three dates in the Verde (e.g.  
792 Rinne in press, Table 4), but other data on channel cross sections may support the trend. The  
793 fish and channel measurement data presented so far (Rinne in press) are too limited for any  
794 statistical inference. Quantification of habitat selection or preference is not available.  
795 Although habitat utilization analyses would strengthen the contention that low gradient  
796 habitats are key, that analysis may not be possible without more detailed and extensive  
797 sampling. The hypothesis that native minnows may select or preferentially use these habitats  
798 is plausible particularly for summer low flow periods when sampling is conducted. It also  
799 seems consistent with the general biological understanding for these species. That does not  
800 exclude the potential importance of other habitats, however. For example other habitat types  
801 or channel elements could become important during extreme events (e.g., drought or flood  
802 refugia) or during other periods of the year when sampling has not been conducted.  
803 Utilization of alternative habitats as refugia during extreme events (e.g. Biro 1998) or in the  
804 face of expanding non-native predation (Olsen and Belk, 2005) could be an important  
805 mechanism for persistence of some native fishes.

806  
807 3. Non-native fishes benefit from narrow, deep channels *and associated habitat types* (e.g.  
808 *pools, high gradient riffles, deep runs, undercut banks*).  
809

810 The observations and evidence supporting this hypothesis are essentially the same as  
811 those outlined above. It also appears that the large bodied native species (suckers, roundtail  
812 chub) use these habitats as well. It is possible that the association between smaller bodied  
813 species and shallow habitat is a behavioral response to the presence of predators in the pools  
814 (not necessarily preferred habitat).

815  
816 4. Native and nonnative spp community structure interacts with valley form, hydrology, and  
817 other geomorphic process.

818  
819 The relative composition of the fish community appears to vary throughout the river.  
820 There is a general pattern favoring non-native species lower in the river and in canyon bound  
821 reaches that is consistent with a geomorphological control on the availability or abundance of  
822 different habitat types. Presumably patterns in channel form and constraint will affect patterns  
823 in habitat availability, species occurrences and abundance, and species interactions. This  
824 hypothesis is plausible and consistent with an expanding literature linking fish species

825 distributions and habitat diversity with geomorphological process (e.g. Poff et al. 2001; Benda  
826 et al. 2004). An association of form and species composition at the reach scale in the Verde  
827 does not mean, however, that changes in channel form will lead directly to changes in species  
828 distribution and abundance. Other processes and conditions also change with valley constraint  
829 and the longitudinal gradient of the river; elevation (temperature and climate), flow volume,  
830 sediment supply, and hydrologic regime all could be correlated with valley form, but not  
831 necessarily linked through process. As a result primary environmental constraints and drivers  
832 on aquatic communities (e.g. carbon source, temperature, disturbance frequency, habitat size  
833 and complexity, substrate size) are changing moving along the longitudinal gradient of the  
834 system. It is impossible to resolve the specific effects without more work or summary of  
835 additional information. For example, it may be possible to demonstrate that specific habitat  
836 types (that can be associated with fishes) vary predictably in abundance, area, or local  
837 characteristics (e.g. depth, velocity, substrate size, area) among reach/geomorphic types or  
838 channel form. Habitat utilization or habitat preference information generated at the habitat  
839 unit scale, might then be used to support the idea that valley form does directly control the  
840 structure of the fish community and is not a spurious correlation linked to other environmental  
841 gradients.

842

843 5. Predation by non-native fishes is an important if not dominant constraint on native  
844 species.

845

846 Non-native predatory fishes including small mouth bass, green sunfish, channel  
847 catfish, and yellow bullhead occur in the UVR. Other predator species occur throughout the  
848 river. Multiple non-native species that may compete with native fishes are also now found  
849 throughout the system. Non-native species are numerically important in fish samples  
850 throughout the Verde River and as a group dominate the fish community. The hypothesis that  
851 non-native predation is a primary constraint on native fishes and a primary cause of their  
852 decline, is, however, limited to circumstantial evidence. Native species numbers have  
853 declined as non-native predators have increased in abundance or expanded in distribution.  
854 There is a negative association spatially among stream reaches as well. Some food habits  
855 research would probably confirm that non-native species prey extensively on native species,  
856 but those data are not available. Predation rates or demographic rates of prey potentially

857 influenced by predation would also help, but cannot be estimated or approximated with  
858 existing data. Predator control efforts have produced no apparent benefit, but the effects of  
859 existing control on predator numbers, dynamics or distribution appear to be limited. There is  
860 detailed and extensive scientific information documenting the capacity of the native and  
861 introduced predatory species to influence the structure of fish communities in riverine and  
862 lake systems so the predation hypothesis is highly plausible. Predator-prey interactions,  
863 however, can be extremely complex and many efforts to manipulate or control the influence  
864 of predation have failed because of non-linear responses or interactions leading to limited or  
865 unanticipated responses in target or native species. There is even evidence that efforts to  
866 control predators can change, size, age, growth or recruitment and actually stimulate predation  
867 (e.g., Rieman and Beamesderfer 1990). Without more detailed information and some  
868 understanding of the critical dynamics it is impossible to conclude where or when predation  
869 has an important influence on abundance or persistence of native species. Non-native and  
870 native species may also interact through competition, physical alteration of key habitats, or  
871 alteration of predator prey dynamics. Red shiner and crayfish appear to be abundant through  
872 much of the upper Verde, for example, and could either directly compete with native  
873 minnows or buffer them from predation by nonnative forms. Those relationships would be  
874 expected to vary with habitat, and relative abundance of individual species.

875  
876  
877

#### 6. Recruitment in native species is facilitated by large floods

878 Fish monitoring in the Verde River initiated after the large 1993 flood event, shows  
879 that relative abundance of juvenile native suckers and roundtail chub and total numbers of  
880 spikedace declined in years subsequent to the flood. The relative dominance of native and  
881 nonnative fishes strongly favored native fishes in 1994-1996, but reversed dramatically in  
882 1997. Native fishes have remained at relatively low levels since that time; spikedace have  
883 disappeared from samples. Native populations did not appear to rebound following moderate  
884 flood events in 2004 and 2005. This may have been because the events were too small to  
885 provide the benefits attributed to flooding or because of other constraints on the populations.  
886 These data are too limited in themselves to lead to a conclusion or statistical support for the  
887 role of flooding and native species recruitment, but they are supported with observations in  
888 other systems (e.g. more frequent flooding and continued dominance of native fishes in the

889 Gila River). The flood benefit hypothesis is also supported through general life history theory  
890 (Olden et al. 2006) and other work (e.g. Minckley and Meffe 1987 cited in Rinne 2005); small  
891 minnows and suckers exhibit two distinct life history patterns reflecting adaptation to frequent  
892 disturbance rather than environmental stability. A general conclusion that flooding can  
893 benefit native species is highly plausible. One problem with any application, however is that  
894 the mechanism is not clear. Flooding may benefit native fishes by creation or rejuvenation of  
895 critical habitats for the fish or their forage that may in turn influence growth or survival, or by  
896 displacement or disruption of non-native predators and competitors, or by any combination of  
897 these. Any relationship between magnitude of flooding, native species response and the  
898 interaction of flooding with changing sediment supply and vegetation is also unknown.

899

900 7. Restoration of wide, shallow, habitats (high width/depth ratio) would reduce  
901 nonnatives and increase native spp abundance (see Attachment 4).

902

903 Based on the evidence associated with the observations and hypotheses outlined  
904 above, a key interpretation is that restoration of wide, shallow habitat types (presumably  
905 through the removal of wood and reintroduction of grazing) would facilitate the recovery of  
906 native fishes by expanding their habitats and simultaneously reducing the habitats for non-  
907 native predators. Assuming that the manipulation of channel morphology is possible, this is a  
908 plausible hypothesis. The data supporting this hypothesis, however, are far from conclusive  
909 and it is also seems plausible that such manipulations could have little value or be detrimental  
910 to native fishes. There are two key limitations to the general hypothesis:

911

912 • It is not clear whether the native: non-native community is controlled primarily by  
913 flood related mortality of non-natives, by flood stimulation of native recruitment, by  
914 channel morphology and habitat capacity regardless of flood history or by some  
915 combination of these. If flooding is fundamentally important through a mechanism  
916 other than alteration of channel morphology, expanding wide, shallow habitats may  
917 only change habitat capacities, but not the interaction of fishes in the habitats that  
918 remain. Changing hydrology (e.g. reduced magnitude or frequency of large floods)  
919 linked to climate and changing sediment supplies (e.g. Ely et al. 1993) could confound  
920 any process or relationship in the future.

921

- 922 • There is a fundamental problem of scaling. It seems unlikely that habitats could be  
923 manipulated throughout the system. How extensive would channel manipulation have  
924 to be to provide some benefit for native fishes? Can they persist and expand in  
925 reaches of a few km or do they require the interconnection of habitats at larger scales  
926 to persist and recolonize those habitats in the face of periodic disturbances (e.g.  
927 drought and flood)? Similarly can nonnative predators exploit areas beyond reaches  
928 that provide primary habitats and how far would that effect extend? Conceivably even  
929 small numbers of non-native predators might range widely with significant influence.

930

931 **4.4. Hypotheses about Interactions:**

932

- 933 1. After 1993 flood, beavers have created new instream habitats, e.g. ponding, slow  
934 water and marsh-like habitats. This raises the following questions the following  
935 questions: what is the role of beavers in the UVR? did the UVR evolve with beaver?  
936
- 937 2. Grazing maintains wet meadows and prevents woody vegetation establishment.  
938
- 939 3. Grazing maintains wide shallow stream habitats (habitat favoring native fishes);  
940 obligate wetland herbaceous vegetation stabilizes banks; once channels are widened,  
941 then herbaceous wetland vegetation stabilizes banks; however, channel form may  
942 change depending on subsequent flows.  
943
- 944 4. Grazing reduces cover of invasive herbaceous plant species; grazing maintains native  
945 plant species.  
946
- 947 5. Multiple factors, including knickpoints, woody vegetation, and debris dams, are  
948 causing channel incision along the UVR.  
949

950 **Response to Hypotheses about Interactions:**

951

- 952 1. After 1993 flood, beavers have created new instream habitats, e.g. ponding, slow water  
953 and marsh-like habitats. This raises the following questions: what is the role of beavers in  
954 the UVR? did the UVR evolve with beaver?

955

956 As noted above, beaver likely had an important role historically in the Verde River  
957 basin and elsewhere in the southwest USA (Butler and Malanson 2005). Early accounts  
958 mention extensive beaver presence and activity in the UVR (Tellman et al. 1997). However,  
959 reconstructing past influences of beaver, as well as beaver removal, is challenging in

960 watersheds throughout the West. Recent reentry of beaver into stream networks, especially  
961 those with pre-reentry data (such as the UVR), provides an intriguing opportunity to  
962 document their current role on stream and riparian habitat, as well as utilization of those  
963 habitats by fish and wildlife.

964  
965 2. Grazing maintains wet meadows and prevents woody vegetation establishment.

966  
967 It is unclear if grazing, either by livestock or native ungulates, maintains wet  
968 meadows. Most of the available literature suggests that meadows, particularly wet meadows  
969 (relative to mesic or drier-end meadows), are negatively impacted by grazing (Belsky et al.  
970 1999; Kauffman et al. 2004). Although the supporting research has not been conducted in  
971 southwestern meadows (Rinne 1999; Clary and Kruse 2004), there is currently no published  
972 data to support this hypothesis for the southwest US or elsewhere in the western USA.  
973 Herbivory can have notable impacts on the growth of woody vegetation, particularly at early  
974 life stages. Heavy livestock grazing can dramatically hinder (even prevent) seedling  
975 establishment of woody riparian trees and shrubs.

976  
977 3. Grazing maintains wide shallow stream habitats (habitat favoring native fishes);  
978 obligate wetland herbaceous vegetation stabilizes banks; once channels are widened, then  
979 herbaceous wetland vegetation stabilizes banks; however, channel form may change  
980 depending on subsequent flows.

981  
982 Indeed, removal of vegetation and bank trampling associated with heavy grazing has  
983 been associated with changes in channel form (wider, shallower channels) (McDowell and  
984 Magilligan 1997). It is plausible that the banks of a wider shallower channel could become  
985 vegetated and that they might be more resistant to erosion than steeper banks along a narrower  
986 channel. It is questionable whether these wide shallower channels are riffles in the classic  
987 sense, and whether managing an entire river to maintain such “riffle” habitat is a reasonable  
988 management goal.

989  
990 It is unclear if a wet meadow system would be less stable in the absence of livestock  
991 grazing. It is likely that wet meadows could remain productive and somewhat resistant to  
992 moderate flooding if moderately grazed; however, the statement that wet meadows are less  
993 stable when ungrazed is unsubstantiated.

994 Bank stability may not be an appropriate measure of stream health along the UVR.  
995 The UVR has historically been characterized by extreme events that remobilize the channel  
996 and floodplain. Whereas wet meadows form in deposits of fines upstream of tributary alluvial  
997 deposits, upstream of beaver dams, and along low floodplains, these features are transient.

998  
999 4. Grazing reduces cover of invasive herbaceous plant species; grazing maintains native  
1000 plant species.

1001  
1002 Livestock grazing removes biomass, and generally results in reduction of both native  
1003 and exotic herbaceous vegetation. Unless exotic species are preferred (no evidence for this  
1004 was presented), grazing could lead to higher cover of aggressive exotic species. In areas with  
1005 high cover of exotic species, grazing may be a valuable tool to remove cover and recover  
1006 native species, but active seeding or planting of natives may be necessary to maintain cover of  
1007 native species.

1008  
1009 5. Multiple factors, including knickpoints, woody vegetation, and debris dams, are  
1010 causing channel incision along the UVR.

1011  
1012 While plausible, there was little compelling evidence from field visits and no data  
1013 presented to suggest that the UVR is actively incising, nor which of these potential factors  
1014 might cause incision in different locations of the river.

1015

## 1016 **5. Review Summary**

1017

### 1018 ***5.1 Upper Verde River: Status of Knowledge***

1019

1020 A goal of the review was to address the following question regarding existing  
1021 knowledge on the UVR: What are major unknowns, particularly those that can potentially be  
1022 addressed through additional research and monitoring efforts? Below, we list the major  
1023 unknowns that were identified during the review and provide input on possible data analyses,  
1024 needed research, and cautions regarding potential limitations of data collected to date.

1025

#### 1026 Vegetation

1027

1028 1. Until the GTR is published, RMRS information on riparian vegetation data from the  
1029 UVR is unavailable, and thus unknown. Currently, vegetative attributes (cover,

- 1030 diversity, composition), changes over time (invasives, valued natives, turnover rates),  
1031 and interactions remain undocumented.  
1032
- 1033 2. Distribution of riparian species, assemblages, and communities (especially valued  
1034 meadow community types) throughout the UVR stream network in relation to valley  
1035 form, geomorphologic surfaces, and channel features is unknown. This includes  
1036 vegetation data from meadows, headwater springs, along tributaries and the mainstem.  
1037 Information could potentially be gained by combining reach-scale vegetation sampling  
1038 (i.e. data to be included in the GTR) with GIS analysis.  
1039
  - 1040 3. The distribution and characteristics of riparian vegetation relative to hydrological  
1041 variables and management activities is unknown.  
1042
  - 1043 4. Estimates of changes in extent of wetlands (area – based) over time are unknown, and  
1044 need to be examined in a spatially explicit watershed context. This could potentially  
1045 be approached by combining reach-scale vegetation sampling, GIS analysis of aerial  
1046 photos to quantify observations #6 and #8 (Text Box), and assist in addressing  
1047 observation #6 and #8 (Text Box).  
1048

#### 1049 Geomorphology

- 1050
- 1051 5. Most of the geomorphic processes are unknown or undocumented at this point (until  
1052 the GTR becomes available).  
1053
  - 1054 6. Hopefully the RMRS data collection will elucidate current channel conditions and  
1055 recent trends, but these results should be placed in a broader context, i.e. are recent  
1056 trends within the range of historic variability, or not?  
1057
  - 1058 7. Understanding of geomorphic processes within tributary basins and across upland  
1059 hillslopes may be necessary for interpreting current conditions and developing  
1060 defensible management strategies.  
1061
  - 1062 8. Larger-scale geomorphic analyses are encouraged. For example, what is the origin of  
1063 the river terraces? Field observations made during site visits and examination of aerial  
1064 photographs suggest that some terraces may be backwater deposits from tributary fans  
1065 that blocked the mainstem river. These depositional environments may structure the  
1066 long-term occurrence of low-gradient habitats for fish and beaver.  
1067

#### 1068 Fish and Aquatic Biota

- 1069
- 1070 9. Formal quantification of habitat selection or preference for native fishes could  
1071 demonstrate the biological significance of distinct habitat types. Although suggestive  
1072 data have been presented, additional research on habitat utilization, particularly during  
1073 periods of stress or extreme flows could be useful as well. If this work is logistically  
1074 infeasible in the Verde, work in other systems or a review of work in similar systems  
1075 or with related species could provide a useful analog.

- 1076 10. The distribution and extent of aquatic habitat types along the UVR has not been  
1077 quantified. This work would be necessary to support any formal analysis of habitat  
1078 selection, but could be useful in itself to understand the magnitude of change  
1079 associated with flooding and management. Inventory and monitoring estimates of the  
1080 total area in distinctly different types quantified with a statistically based sampling  
1081 design would help understand habitat availability and change that occurs with  
1082 disturbance and any intentional manipulation. Existing data might be used for an  
1083 initial approximation of habitat availability and design for future work.  
1084
- 1085 11. The potential mechanisms driving the assumed relationships between non-native  
1086 species and native species are unclear. Research quantifying native species population  
1087 dynamics (e.g., growth, mortality, and recruitment), native-nonnative food webs, and  
1088 predation rates could help clarify the relative importance of the different alternatives.  
1089
- 1090 12. Scaling of habitat utilization and species interactions is unknown. Assuming habitat  
1091 conditions do influence or control the fish community structure, the extent of habitat  
1092 alteration that might be needed to benefit native species is unknown. Studies to  
1093 quantify the extent of foraging and life history movements for both native and non-  
1094 native species might help clarify the scaling important to population responses. If  
1095 direct measurements of the processes influencing population dynamics and structure  
1096 are not possible genetic tools might be useful, but application with the species in these  
1097 systems would require further work to determine feasibility.  
1098
- 1099 13. The extent of intentional grazing and channel habitat manipulation possible within  
1100 physical, ecological and political constraints is unknown. The detailed mechanistic  
1101 studies outlined above are likely to be time consuming and expensive and may yield  
1102 uncertain results. Management-research experiments rather than detailed mechanistic  
1103 research may be the most effective way to resolve the uncertainties associated with  
1104 grazing, native fishes, and introduced fishes but the logistical, scientific, and political  
1105 constraints on such experiments will require thoughtful discussion and development.  
1106 Experimental grazing and vegetation management might be attempted in select  
1107 reaches. With a valid experimental design it may be possible to determine the extent  
1108 of manipulation in channel/habitat response possible within existing physical,  
1109 ecological and political constraints. The experimental manipulation of predator  
1110 species could be continued, but research may need to be expanded to effectively  
1111 quantify dynamics of the predator and prey populations and understand the magnitude  
1112 of change required for any meaningful response.  
1113

1114 Interactions, processes, other:  
1115

- 1116 14. An understanding of the overall condition of the Verde River watershed is lacking.  
1117 Existing watershed assessments could be expanded to include areas influenced by  
1118 recreation, roads, upslope gravel mining; upland grazing; activities on private in  
1119 holdings (TNC and ranchers); biotic inventories (in addition to plants and fish);  
1120 distribution of aquatic and riparian habitat types; seasonal surface water chemistry and  
1121 temperature at multiple, selected locations within the basin (including springs and

1122 tributaries); and continued evaluation of biota relative to hydrologic variables,  
1123 physical features, and both riparian and upland land use.

1124

1125 15. Influence of management activities, including grazing, and human impacts (e.g.  
1126 unmanaged recreation) on riparian vegetation, fish species, aquatic-terrestrial habitat,  
1127 and hillslope-channel physical features have not been quantified or documented  
1128 beyond photo comparisons. In addition, the influence of management on natural  
1129 processes and interactions among biota and physical features is unknown. Focused,  
1130 well-designed experimental research is needed to address interactions and the  
1131 influence of management in the UVR basin, as well as other Arizona rivers.

1132

1133 16. With the exception of the sampling efforts shown in Table 1, no data have been  
1134 collected by RMRS on most groups of aquatic-riparian biota, including riparian and  
1135 aquatic micro-and- macroinvertebrate assemblages, aquatic autotrophs  
1136 (phytoplankton, periphyton, macrophytes), microbial organisms, invasive species of  
1137 concern (Asiatic clam, crayfish, and bullfrogs), and valued species of concern  
1138 (lowland leopard frogs, neotropical migrant bird species, bats). Some data were  
1139 collected by other groups including university and agency scientists.

1140

1141 17. No information has been collected on basic stream-riparian ecological processes in the  
1142 UVR, including seasonal nutrient cycling and organic matter dynamics, aquatic-  
1143 terrestrial food webs, large wood dynamics, and species interactions (competitive,  
1144 beneficial, other). Aspects of these processes, particularly in relation to management  
1145 or human modification of the river, may be critical to understanding the disappearance  
1146 and decline in native fish populations.

1147

1148 18. Interactions between and among riparian vegetation, channel features (substrates,  
1149 dimensions, form), and distribution of aquatic-riparian vertebrate populations (fish,  
1150 amphibians, birds) are unknown. Although work by RMRS scientists has increased  
1151 understanding of habitat preferences for certain native fish species, considerably more  
1152 information is needed. No interactions have been documented.

1153

1154 We recognize that exploring the listed ‘unknowns’ is beyond the current scope of  
1155 research and monitoring capabilities of RMRS and the PNF and will require broader  
1156 collaboration with other partners, including state agencies (Arizona Game and Fish  
1157 Department), USGS researchers, local universities, and USFWS. Since so few data have been  
1158 collected on the UVR, RMRS monitoring information may be an important contribution to  
1159 current understanding of the river. It is important that existing data be fully utilized and  
1160 analyzed and made available as soon as possible, so that efforts are not repeated or duplicated  
1161 by others. Once published, we recommend that the GTR be given broad distribution and that  
1162 RMRS become more actively engaged with the wide range of stakeholders who have been  
1163 meeting to discuss the future of the Upper Verde River.

1164 In addressing ‘what is known about the UVR’, two recent reports provide timely  
1165 information on the status of knowledge. The first is USGS Open-File Report 2004-1411,  
1166 entitled ‘Geologic Framework of Aquifer Units and Ground-Water Flowpaths, Verde River  
1167 Headwaters, North-Central Arizona (Wirt et al., 2004; <http://pubs.usgs.gov/of/2004/1411>) and  
1168 focuses on the physical features of the Verde River basin, particularly the hydrology of the  
1169 upper portion. The second is a report produced by The Nature Conservancy (TNC), entitled  
1170 ‘Ecological Implications of Verde River Flows’ (Haney et al. 2008;  
1171 <http://www.biologicaldiversity.org>; accessed March 2008). Collectively, these two reports  
1172 (and citations within) provide a comprehensive summary of published work to date.  
1173 However, both reports emphasize how little is really known about the Verde River.

1174  
1175 ***5.2 Science Needs Assessment***  
1176

1177 This section is an extension of our responses to the hypotheses in Section 4, and  
1178 further addresses discussions that occurred during the review. We do not mean to imply that  
1179 these are priority management questions for the PNF, since they have already been identified.  
1180 Nor do we intend that these comments identify high-priority research questions for the  
1181 RMRS. Rather, they are intended as an assessment of the potential areas for integration of  
1182 existing information and management of the UVR, RMRS monitoring efforts, and  
1183 management questions posed by the PNF. The review illuminated the complex ecological  
1184 issues related to potentially conflicting management objectives in a sometimes contentious  
1185 socio-political climate. The staff of the PNF face difficult decisions to achieve the broader  
1186 objectives of conservation of ecological diversity, and restoration and maintenance of  
1187 ecosystem function while providing a sustainable delivery of goods and services demanded by  
1188 their permittees and the general public.

1189  
1190 As noted above, it is difficult to evaluate the riparian vegetation and geomorphological  
1191 aspects of the work that has been conducted by RMRS personnel, because we were not  
1192 presented with any summaries of the data, graphs, statistics or conclusions from data analyses.  
1193 However, the conclusions that have been reached and were shared with the group implied that  
1194 much is known about the riparian vegetation of the UVR and that the positive effects of  
1195 grazing are fairly clear. Currently, these conclusions remain unsupported and valid objections

1196 to them could be raised. For example, the conclusion that livestock grazing along the UVR  
1197 contributes to the maintenance of endangered fish habitat is questionable given the lack of  
1198 data indicating patterns that would suggest such habitat is more abundant along reaches  
1199 lacking woody vegetation. Many linkages in process are made with little data to support them  
1200 (grazing >> riffles >> fish habitat). The desired state described by RMRS personnel for  
1201 riparian areas along the UVR includes a stable, wide, shallow channel bordered by grazed  
1202 meadow. It is unclear whether this will indeed provide abundant riffle habitat for native  
1203 fishes along the UVR, but it seems unlikely to us that this scenario bears resemblance to  
1204 historical conditions along the UVR.

1205

1206           The Verde River is unique in Arizona in that it is perennial along much of its length.  
1207 However, it also experiences floods orders of magnitude larger than low flow. The system  
1208 has a rich supply of sediment from surrounding hillslopes and tributaries and the channel and  
1209 bed are comprised of alluvium along much of its length. The frequent large flood events  
1210 likely restructure the channel regularly, facilitating the establishment of disturbance adapted  
1211 species such as willow, cottonwood, seep willow, and suites of annual and short-lived species.  
1212 Over time the river recovers between disturbances and less-disturbance adapted species can  
1213 become established. Through time the UVR supports very diverse and dynamic riparian  
1214 vegetation. Though wet meadows are components of this system, particularly during longer  
1215 intervals between floods (Heffernan 2008), woody vegetation has likely always been an  
1216 important component of this system. Early accounts from the 1850's suggest that there were  
1217 abundant forests and riparian shrublands along the Verde River and its tributaries, and that  
1218 there were marshes and wet meadows associated with beaver dams (Leopold 1951; Shaw  
1219 2006). RMRS personnel indicated that beaver were introduced and that they were undesirable  
1220 because they facilitate channel incision through dam failure. Based on early accounts from  
1221 the region, beaver trapping was common throughout the Gila and Verde Rivers in the 18<sup>th</sup>  
1222 century and earlier (Leopold 1951; Blinn and Poff 2005).

1223

1224           Observations for the Upper Verde River by the PNF (Leonard's Briefing Paper)  
1225 stated: "We have witnessed significant losses of sedge-dominated wetlands, important habitat  
1226 for lowland leopard frogs, garter snakes and other wildlife." During the review, we were

1227 shown a low gradient reach with on-going beaver activity that, according to photos from the  
1228 mid 1990's, had been an extensive 'sedge-dominated wetland'. We were informed that wet  
1229 meadows, which this site once was, are important habitat and breeding sites for lowland  
1230 leopard frogs (*Rana yavapaiensis*), garter snakes, and other wildlife on the Upper Verde.  
1231 Leopard frogs had not been observed for some time, and the PNF associated the frog's  
1232 disappearance, in part, with changes to its habitat. However, lowland leopard frogs utilize a  
1233 variety of habitats and are not wetland or pond obligates. They inhabit permanent stream  
1234 pools often overgrown with willows and cottonwoods, as well as side channels and stock  
1235 tanks. They rely on debris piles, root wads, and undercut banks for cover (Sredl 2005). On  
1236 Fossil Creek, tributary to the lower Verde River, Coconino NF biologists recorded frogs  
1237 successfully breeding along stream channels amid overhanging cottonwoods and sycamores  
1238 (Agyagos 2006).

1239

1240 We advocate that a full range of alternative hypotheses, in addition to the cessation of  
1241 livestock grazing, be considered to explain changes in occurrence of native fauna and  
1242 condition of riparian and aquatic habitat. Regarding the possible extirpation of lowland  
1243 leopard frogs from the upper Verde River, a more likely cause than loss of suitable habitat  
1244 may be the presence of nonnative aquatic species. The low frequency of lowland leopard  
1245 frogs in mainstem rivers has been attributed to the presence of large populations of non-native  
1246 organisms, including fishes, bullfrogs, and crayfish (Sredl *et al.* 1997). In a recent study,  
1247 Witte *et al.* (2008) examined over a dozen environmental risk factors that may be associated  
1248 with local disappearances of native ranid frogs, including lowland leopard frogs, in Arizona.  
1249 The presence of introduced crayfish was one of the few factors significantly correlated with  
1250 leopard frog disappearance, likely through predation and competition. The negative impact of  
1251 invasive crayfish (abundant in the upper Verde River) on native fish and herpetofauna may be  
1252 greater than shifts in riparian vegetation.

1253

1254 There are limitations to existing fish/habitat information; however, this is not a  
1255 criticism of the work. Past efforts and existing data on fishes and their habitats were done on  
1256 very limited funding and were not designed to answer questions or limitations like the ones  
1257 posed above. Existing data provide critical information about the status of native species,

1258 important clues about the causes, and a foundation for hypothesis generation and the design of  
1259 more detailed ecological studies. The current hypotheses are plausible and supported in  
1260 theory and some observation from other systems. It is not possible, however, to predict with  
1261 any confidence what, if any, habitat manipulations or management actions would lead to the  
1262 restoration of native fishes. Addressing this hypothesis will require detailed ecological  
1263 research or large scale management experiments, or both. There are important challenges to  
1264 either approach, but management experiments designed through some collaboration of  
1265 research, management, and other public-private interests could probably resolve critical  
1266 uncertainties more quickly. Whether those experiments are even possible and the scale  
1267 needed to gain meaningful information will require considerable discussion and debate.

1268

1269         The values implied by restoration ecology and conservation biology are often at odds  
1270 (e.g. Noss et al. 2006). It is important for managers to recognize the difference and clearly  
1271 articulate their goals and objectives in that context. It is implausible to us that the Verde  
1272 River existed over evolutionary and important ecological time scales (100s to 1000s of years)  
1273 without a substantial and dynamic flux of riparian vegetation including larger woody species.  
1274 The period around the turn of the 19<sup>th</sup> century was unprecedented in the frequency of major  
1275 floods in the region (Ely et al. 1993) that in combination with heavy grazing might well  
1276 explain the apparent lack of riparian vegetation in the early 20<sup>th</sup> century. The flood record  
1277 suggests anything but constancy and we would expect a system that varied through a broad  
1278 range of geomorphic and ecological conditions driven by flood, drought, and vegetation  
1279 succession through space and time. The native species complex evolved in that context and  
1280 had the capacity to persist with it. Non-native species (fish and plant), loss of water, changing  
1281 sediment supply, and other stresses have undoubtedly altered that. But, our sense is that the  
1282 Verde still has the capacity to express some of the native diversity and dynamics.

1283

1284         Staff from the PNF expressed concern that the Pacific Northwest “trout model” still  
1285 greatly influences perceptions of watershed condition and restoration in arid streams. Their  
1286 point, that a management paradigm supporting attempts to create or maintain deep, narrow  
1287 streams with high frequencies of pools may be inappropriate for flood-sediment driven desert  
1288 streams, is well taken. There is a growing realization that natural disturbance and

1289 heterogeneity of habitats in time and space is the appropriate model in most systems. Current  
1290 theory and a growing body of empirical evidence argues that maintenance of biological  
1291 diversity and adaptive potential depends more on restoring or maintaining natural disturbance  
1292 regimes and the integrity-connectivity of upland-riparian systems and stream networks that  
1293 allow biological communities to vary and respond as they have over evolutionary/ecological  
1294 time scales. It also recognizes that these systems are changing, potentially toward  
1295 unprecedented conditions, in response to climate change, species invasions, and inescapable  
1296 human disruption. Research that elucidates appropriate models for the processes that  
1297 dominate southwestern arid river systems may help the PNF meet the broader goal of creating  
1298 and maintaining systems that have the potential to function, adapt, and provide as many of the  
1299 natural services and values as possible with limited human intervention, even if they do not  
1300 maintain the strict ecological integrity implied by communities of purely native species (e.g.  
1301 Calicott 1995; Calicott and Mumford 1997).

1302

1303           We do not expect that the forthcoming General Technical Report will completely  
1304 resolve the many questions identified in this review. However, it may provide useful analyses  
1305 and additional information that will provide the sound scientific basis for future management  
1306 decisions.

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1437 **Attachments:**

1438

1439 1. Review team with contact information and website links.

1440 2. Review participants during visit, April 7-11, 2008.

1441 3. Handout provided by John Rinne: Upper Verde River; Status of Information on Fishes,

1442 1994-2006 (prepared Feb, 2007).

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1490 Attachment 2. Review Participants

Name	Title	Affiliation	Participation
Kate Dwire	Research Riparian Ecologist	RMRS	April 7-11, all activities
David Merritt	Riparian Plant Ecologist	Stream Systems Technology Center	April 7-11, all activities
John Buffington	Research Geomorphologist	RMRS	April 7-11, all activities
Bruce Rieman	Research Fisheries Ecologist	RMRS, retired	April 7-11, all activities
Cynthia Tait	Regional Aquatic Ecologist	NFS, R4	April 7-11, all activities
Kerry Overton	Acting Program Manager Air, Water & Aquatic Environments Science Program	RMRS	April 7-11, all activities
Daniel Neary	Research Soil Scientist	RMRS	April 7-9, all activities; April 11, wrap-up meeting
Alvin Medina	Rangeland Specialist	RMRS	April 7-9, all activities; April 11, wrap-up meeting
John Rinne	Research Fisheries Ecologist	RMRS, retired	April 7, presentations April 10, presentation and field visit
Mike Leonard	Staff Officer for Planning, NEPA, Wildlife, Fish and Rare Plants	Prescott NF	April 7, presentations April 8, field visit
Linda Jackson	District Ranger, Chino Valley Ranger District	Prescott NF	April 7, presentations
Larry Bright	WFRP Team Leader	Prescott NF	April 7-9, all activities; April 11, wrap-up meeting
Janet Grove	Riparian Ecologist	Tonto NF	April 8-9, field visits
Jackson Leonard	Technician	RMRS	April 7, presentations April 8, 9, 10 field visits

1491 Attachment 3. Handout provided by John Rinne: Upper Verde River; Status of Information on Fishes,  
1492 1994-2006 (prepared Feb, 2007).

1493  
1494 UPPER VERDE RIVER  
1495 STATUS OF INFORMATION ON FISHES, 1994-2006

1496  
1497 John N. Rinne  
1498 RMRS  
1499 February, 2007  
1500

1501  
1502 RMRS has been monitoring and studying fish assemblages and factors potentially affecting  
1503 these assemblages in the upper 60 km of the Verde River since 1994. Information has been published  
1504 in numerous outlets (Appendix A). Activities have included monitoring fishes and their habitats since  
1505 flooding in winter 1992-93, mechanical removal of predators 1999-2003 and summer 2006, and  
1506 spikedace monitoring. In spring 2007, there will be 14 years of data at seven fixed monitoring sites  
1507 over the upper 60 km reach.  
1508

1509 Important relationships and changes in fish assemblages have been documented and  
1510 unfavorable trends in native fishes have a high probability of repeating themselves. These are:

- 1511
- 1512 1. Native fishes were abundant and dominated fish assemblages only for a short  
1513 term post-flooding in 1994-96 and 2006-?  
1514
  - 1515 2. Spikedace were abundant only from 1994-1996, at the extreme upper end of  
1516 sampling reach. The species has not been collected since 1997.  
1517
  - 1518 3. Nonnative fishes became dominant during the extended low flow, drought  
1519 period (1996-2003); three species of native fishes (including the  
1520 threatened spikedace) became markedly reduced ((70%) and have  
1521 virtually disappeared in samples.  
1522
  - 1523 4. Pilot mechanical removal activities from 1999-2003 failed to accrue any benefit  
1524 to native species. A modified removal approach was initiated in 2006,  
1525 however, funding is currently inadequate to continue this program.  
1526
  - 1527 5. Nonnative species are markedly, and steadily increasing once again based on  
1528 monitoring at the seven long term sites.  
1529
  - 1530 6. Flooding and the nature of the upper Verde River hydrograph has been the  
1531 primary, positive factor to sustain native fishes.  
1532
  - 1533 7. Base, drought flows and attendant livestock grazing removal appears to be the  
1534 primary activities that enhance nonnative fishes in the upper Verde.  
1535

1536  
1537 In summary, in absence of significant flooding, continued base flows and livestock exclusion,  
1538 native fishes will once again decline and in some cases disappear from the upper Verde River. By  
1539 contrast, nonnatives species will increase and dominate the fish assemblage in the upper Verde.  
1540 Spikedace re-appearance will have an increasingly lower probability.  
1541

APPENDIX A

Upper Verde Published Information

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1626 23. **Rinne, J. N.**, Miller, D, and Medina, A. L. IN PREP. Riparian restoration with livestock grazing  
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1628

### I. UPPER VERDE RIVER WATERSHED

