STUDY PLAN TO EXAMINE THE EFFECTS OF USING LARVAL RAZORBACK SUCKER OCCURRENCE IN THE GREEN RIVER AS A TRIGGER FOR FLAMING GORGE DAM PEAK RELEASES

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EXECUTIVE SUMMARY

Flow recommendations were developed for the Green River below Flaming Gorge Dam by Muth et al. (2000) to assist with conservation and recovery of endangered fishes. These flow recommendations identified annual peak flow magnitudes and durations needed to connect the river to razorback sucker floodplain nursery habitats in the middle Green River (Table 1). In order to achieve these recommended peak flow magnitudes and durations, the Bureau of Reclamation (Reclamation) has timed the release of water from Flaming Gorge Reservoir to match the peak flow in the Yampa River. A primary purpose of those spring operations at Flaming Gorge Dam is to provide nursery habitat for endangered razorback sucker (*Xyrauchen texanus*) in the middle Green River so early life stages (larvae) can access productive floodplain wetlands via connections with the river. Despite successfully meeting or exceeding peak flow magnitudes and durations in the targeted reach, consistent and substantial razorback sucker recruitment has not been observed. In a recently completed synthesis report (Bestgen et al. 2011), researchers concluded that in most years since 1993, releases from Flaming Gorge Dam occurred too early relative to presence of razorback sucker in the Green River. They recommended that the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) and Reclamation implement a schedule of altered timing of flow releases from Flaming Gorge Dam to coincide more closely with presence of razorback sucker larvae, or perhaps, presence of abundant larvae, in the middle Green River. The Recovery Program has proposed that Reclamation use the occurrence of razorback sucker larvae in channel margin habitats (as determined by real-time monitoring) as the "trigger" to determine when peak releases should occur from Flaming Gorge Dam. Determining the effectiveness of this larval trigger in recruiting razorback suckers is the primary focus of this study plan, but other potential effects would also be evaluated.

Evaluating the effectiveness of operating Flaming Gorge Reservoir using a larval trigger requires a targeted hypothesis-based monitoring and research program that examines aspects of the life cycle and recruitment limitations of razorback sucker. The topics to be examined under the study plan, hypotheses to be tested within each, and the general methods to be employed are described here. Five topics are included in this plan: (1) entrainment and retention of larval razorback suckers in floodplain wetlands; (2) survival of larvae and escapement of juvenile and adult fish entrained as larvae into floodplain wetlands; (3) availability of young-of-the-year Colorado pikeminnow habitat at base flow; (4) sediment mobilization and channel maintenance; and (5) fish community response. Studies associated with Topics 1 and 2 are considered the highest priority because these studies address razorback sucker entrainment and recruitment, which are the intended benefits of using a larval trigger. Information from other species, particularly co-evolved native catostomids, as well as historical information, will be used to support patterns observed for razorback sucker particularly if their larvae are rare in some years. Topics 3, 4, and 5 address other potential consequences of using a larval trigger, and, although important, are considered lower priority for testing the efficacy of using a larval trigger. A total of nine hypotheses are identified under Topics 1 and 2; an additional eight hypotheses are identified under Topics 3, 4, and 5.

Wetlands that hold the greatest promise for entraining and recruiting razorback suckers, and that are representative of other wetlands in the system should be the focus of studies

developed under this plan. Because study wetlands connect with the main channel at different flow levels, some can only be studied at higher peak flows. Under the study plan, up to eight wetlands would be sampled in a given year with the three in the lowest flow category (Stewart Lake, Above Brennan, and Old Charley Wash) being sampled in all years. As practicable, proposed studies should address a range of flow magnitudes and durations, and we consider three years with flows < 18,600 cfs and three years with flows $\underline{\geq}$ 18,600 cfs, with connecting flows in each of these years of at least seven days duration, as minimally necessary to complete the study.

The specific objectives, tasks, and expected outcomes for individual studies developed under this plan will be identified in statements of work approved by the Recovery Program. These projects and the resulting project reports will go through the standard Recovery Program review protocols. It is anticipated that in addition to an annual review of the data collected, a synthesis report will be developed that summarizes results from individual projects, integrates results, summarizes conclusions, and makes recommendations for future implementation of a larval trigger. As for any study plan, additional knowledge will be gained during implementation, and it will be important to have enough flexibility to adjust studies and overall approaches in response to this new information. Toward this end, the results of studies will be evaluated each year to determine the need for modification.

This Study Plan was drafted by an *ad hoc* Committee, which included representatives from Reclamation, Western Area Power Administration, Colorado State University, U.S. Fish and Wildlife Service, National Park Service, Argonne National Laboratory, and environmental interests. Development of the Study Plan was coordinated by the Recovery Program and benefited greatly from input by members of the Biology Committee and principal investigators conducting studies in the Green River Subbasin.

1 INTRODUCTION

The razorback sucker (*Xyrauchen texanus*), an endemic species of the Colorado River Basin, is federally listed as endangered. A critically important population of this species inhabits the middle Green River, Utah, between the confluence of the Yampa River downstream to the head of Desolation-Gray Canyon. Razorback suckers congregate in spring at two spawning areas in the upstream portion of the reach, at Razorback (river kilometer [RK] 500.9) and Escalante (RK 493.7) spawning bars, and have successfully reproduced from 1992-2011, as evidenced by annual collections of larval fish downstream of spawning areas (Bestgen et al. 2011; annual Recovery Program reports, Project 22f). However, very few naturally produced razorback suckers recruit from the larval stage to sexual maturity. Researchers believe that in order to successfully recruit, young-of-the-year (YOY) need to overwinter for one or more years in off-channel floodplain nursery habitats before returning to the main channel (Muth et al. 2000). Because the river must reach a specific height before each nursery habitat is connected to the main channel, recruitment of larval razorback suckers to adulthood is closely tied to high spring peak flows.

Flow recommendations (Muth et al. 2000) were developed for the Green River downstream of Flaming Gorge Dam to provide the necessary flows to support recovery of the razorback sucker and three other endangered fishes in the Green River (Colorado pikeminnow, *Ptychochelius lucius*; humpback chub, *Gila cypha*; and bonytail, *G. elegans*). These flow recommendations identified annual peak flow magnitudes and durations, as measured at the Jensen, Utah gage (U.S. Geological Survey [USGS] gage 09261000), needed to connect the river to razorback sucker floodplain nursery habitats in the middle Green River (Table 1). Although connection of these habitats to the river appears to be critical to razorback sucker recovery, connection is only biologically meaningful if it occurs when razorback sucker larvae are drifting in the water column and available for transport into floodplain habitats. In addition, floodplain wetland habitats must consistently offer suitable habitat (i.e., sufficient size, depth, and water quality) to support fish until subsequent annual peak flows reconnect habitats to the river and allow for escapement of subadults.

Following the Record of Decision for the Flaming Gorge environmental impact statement published in 2006, the Bureau of Reclamation (Reclamation), as operator of Flaming Gorge Dam, and in collaboration with the interagency Flaming Gorge Technical Work Group, has provided annual peak flows that meet or exceed the annual peak flow recommendations presented in Muth et al. (2000). In order to achieve these recommended peak flow magnitudes and durations, Reclamation has timed the release of water from Flaming Gorge Reservoir to match the peak flow in the Yampa River, thus, minimizing the amount of released water needed to achieve the peak flow targets. Although this operational approach is consistent with the recommendations in Muth et al. (2000), a recent synthesis by Bestgen et al. (2011) suggests that it may not be accomplishing its intended biological purpose, i.e., to provide for successful recruitment of razorback suckers. Razorback sucker recruitment has not been observed since the Record of Decision despite successfully meeting or exceeding target peak flow magnitudes and durations.

TABLE 1. Spring Peak Flow Recommendations for the Green River between the Confluences of the Yampa and White Rivers (Muth et al. 2000).[(a)]

	Hydrologic Condition				
	Wet (0 to 10% Exceedance)	**Moderately Wet (10 to 30% Exceedance)**	**Average (30 to 70% Exceedance)**	**Moderately Dry (70 to 90% Exceedance)**	**Dry (90 to 100% Exceedance)**
General recommendation	Peak flows should be of the magnitude, timing, and duration to provide floodplain inundation in the Ouray portion of the river for at least 2 weeks in 4 of 10 years and at least bankfull flows in 1 of 2 years. In all years, peak flows should be of sufficient magnitude and duration to provide at least some in-channel habitat maintenance throughout the reach. No upper limits are placed on recommended peak flows in any hydrologic condition. The duration of peak flows less than 527 m^3/s (18,600 cfs) should be limited, because neither floodplain nor backwater habitats are available at these flows.				
Peak-flow magnitude	$\geq$ 748 m^3/s (26,400 cfs)	$\geq$ 575 m^3/s (20,300 cfs)	$\geq$ 527 m^3/s (18,600 cfs) in 1 of 2 average years; $\geq$ 235 m^3/s (8,300 cfs) in other average years	$\geq$ 235 m^3/s (8,300 cfs)	
Peak-flow duration	Flows > 643 m^3/s (22,700 cfs) should be maintained for 2 weeks or more, and flows greater than 527 m^3/s (18,600 cfs) for 4 weeks or more.	Flows > 527 m^3/s (18,600 cfs) should be maintained for 2 weeks or more.	Flows > 527 m^3/s (18,600 cfs) should be maintained for at least 2 weeks in at least 1 of 4 average years.	Flows >235 m^3/s (8,300 cfs) should be maintained for at least 1 week.	Flows > 235 m^3/s (8,300 cfs) should be maintained for 2 days or more except in extremely dry years ($\geq$ 98% exceedance).
Peak-flow timing	Peak flows should coincide with peak and immediate post-peak spring flows in the Yampa River.				

(a) All flow targets are as measured at the Jensen, Utah gage (USGS 09261000).

Bestgen et al. (2011) evaluated the effectiveness of matching Yampa River Peak flows with high releases from Flaming Gorge Dam, and found that after 1993 releases were premature relative to larval razorback sucker drift. They found that by the time razorback sucker larvae were drifting, peaks flows were often receding, which limited the number of days of connection to floodplain nursery habitats and reduced the opportunity for entrainment of larvae. This led them to conclude that

> "*Longer duration and especially, higher magnitude flows, timed to occur when razorback sucker larvae were present, may be minimally sufficient conditions to enhance recruitment of razorback suckers in the middle Green River, Utah.*"

Bestgen et al. (2011) provided a number of recommendations related to developing a better understanding of the relationships between the timing of drift, entrainment rates of larvae

in floodplain wetland habitats, the ability of different floodplain wetland habitats to overwinter fish, and timing peak flows to coincide with larval drift periods. Recommendations, paraphrased from the original text, included:

- Study early life history of razorback sucker in the Green River Basin to better understand the role of altered spring thermal ecology on timing of spawning, development of embryos, and emergence of razorback sucker larvae, as well as the potential effects on spawning of nonnative fishes.

- Determine timing of spawning, hatching, emergence, habitat use, and survival of razorback sucker larvae in the lower Green River [Reach 3 of Muth et al. 2000]. This may be especially important if timing of releases from Flaming Gorge Dam, or flow magnitude or duration, is altered.

- Evaluate utility of floodplain wetlands as recruitment habitat for early life stages of razorback sucker. Important aspects include colonization/entrainment rates of larvae into single-breach wetlands, utility of terrace wetlands as temporary habitat for razorback sucker larvae, and sedimentation of breaches.

- Evaluate utility of floodplain wetlands as overwinter habitat for young razorback sucker, and develop plans to enhance fish overwintering capability of key wetlands.

- Consider utility and feasibility of scheduling filling of gated wetlands with Green River water only when high densities of razorback sucker larvae are present.

- Develop a simple population dynamics tool to assist with modeling entrainment and survival rates of early life stages of razorback suckers in various floodplain wetlands.

- Implement a schedule of altered timing of flow releases from Flaming Gorge Dam to coincide more closely with presence of razorback sucker larvae, or perhaps, presence of abundant larvae, in the middle Green River. Reliable real-time monitoring is already in place to guide timing of releases. In lieu of that, develop relationships based on physical attributes, mostly water temperature and time of year, which would predict timing of emergence.

- Investigate the feasibility of increased magnitude and duration of spring flow releases from Flaming Gorge Dam, after razorback sucker larvae are present, to maintain connections with floodplain wetlands and increase entrainment rates. Subsequent effects on base flow levels, among other biotic and abiotic factors, will also need to be considered.

On the basis of the findings and recommendations in Bestgen et al. (2011), the U.S. Fish and Wildlife Service's (USFWS) Upper Colorado River Endangered Fish Recovery Program (Recovery Program) requested that releases from Flaming Gorge Reservoir in the spring of 2011 be experimentally timed to coincide with the occurrence of razorback sucker larvae in the middle Green River. Unusually high Yampa River flows, inflows to Flaming Gorge Reservoir, and Flaming Gorge Dam releases resulted in extended periods of connection between river and

floodplain habitats during the larval drift period of 2011. Flows were continuously ≥ 18,600 cfs for more than 40 days in 2011, and razorback sucker larvae were present for at least 19 of those days (Recovery Program annual report, project 22f; K. R. Bestgen, unpublished data).

The Recovery Program has proposed that Reclamation use the occurrence of razorback sucker larvae in channel margin habitats (an indication that larval drift is occurring in the river) as the "trigger" to determine when peak releases should occur from Flaming Gorge Dam. This "larval trigger" would initially be implemented during an experimental period of about six years, depending on flows conditions realized, and is consistent with the Muth et al. (2000) flow recommendations in which initial appearance of larval suckers was identified as one of several examples of real-time information to be considered when determining the onset of spring peak flows (see Table 5.3 of Muth et al. 2000). Determining the effectiveness of this larval trigger in recruiting razorback suckers is the primary focus of this study plan, but other potential effects are also evaluated. Based on information in Bestgen et al. (2011), using the larval trigger would shift the timing of Flaming Gorge peak releases to later in the runoff period. For the 1993 to 2008 period examined in Bestgen et al. (2011), the shift in timing of releases relative to peak Yampa River flows could be earlier, about the same, or as much as 17 days later if the first detection of larvae was used as the trigger, based on comparison of timing of flow releases in that period relative to first occurrence of larvae for those 16 years.

2 PROPOSED MONITORING AND RESEARCH

The Green River Study Plan (Green River Study Plan *ad hoc* Committee 2007), identified studies to evaluate the effectiveness of the flow recommendations of Muth et al. (2000). One of these recommended studies was the floodplain synthesis performed by Bestgen et al. (2011). This larval trigger study plan is a consequence of the findings of studies identified in the original Green River Study Plan, and is considered an important next step by the Recovery Program Biology Committee towards refining the implementation of the flow recommendations.[1]

Evaluating the effectiveness of operating Flaming Gorge Reservoir under a "larval trigger" scenario requires a targeted hypothesis-based monitoring and research program. The topics to be examined under the study plan, hypotheses to be tested within each, and the general methods to be employed are described here. Five topics are included in this plan: (1) entrainment and retention of larval razorback suckers in floodplain wetlands; (2) survival and eventual escapement of larvae entrained in floodplain wetlands; (3) availability of YOY Colorado

[1] This next step in refining the implementation of the flow recommendations is consistent with the expression of Reclamation's intent in the 2006 Record of Decision (ROD) "to work through the Upper Colorado Endangered Fish Recovery Program, along with the cooperating agencies on the EIS and the interested public, to assess the possibility of improving connectivity of floodplain habitats, identifying ways to improve entrainment of larval razorback suckers into floodplain habitats, maintain the river channel, restore natural variability of the river system, and meet other goals of the Flow and Temperature Recommendations at lower peak flow levels where feasible." The 2006 ROD also recognizes that "such additional knowledge gained through the adaptive management process may result in future refinement of the 2000 Flow and Temperature Recommendations that would maintain or improve conditions for the four endangered fish species while minimizing negative effects to the authorized purposes of Flaming Gorge Dam."

pikeminnow habitat at base flow; (4) sediment mobilization and channel maintenance; and (5) fish community response. Studies associated with Topics 1 and 2 are considered the highest priority because these studies address razorback sucker entrainment and recruitment, which are the intended benefits of using a larval trigger. Information from other species, particularly co-evolved native catostomids, will be used to support patterns observed for razorback sucker particularly if razorback larvae are rare in some years. Topics 3, 4, and 5 address potential other consequences of using a larval trigger, and, although important, are considered lower priority for testing the efficacy of using a larval trigger. It is important to note that the priorities assigned to topics in this study plan are relative to their importance to testing the effectiveness of implementing the larval trigger and not to overall priorities of the Recovery Program. Wherever possible, the study plan identifies existing projects that could be modified or expanded to test hypotheses, in order to capitalize on well-established protocols.

Floodplain wetlands in the middle Green River consist of terrace and depression wetlands (Irving and Burdick 1995; Valdez and Nelson 2004). Floodplain depressions hold water for an extended period of time because they are separated from the river by higher ground (natural or manmade levees), but terrace wetlands do not hold water, and fill and drain as the river rises and falls. Some depression wetlands may provide important nursery habitat for the entire period between sequential annual peak flows, thus augmenting recruitment of juveniles and sub adults into riverine habitats. Because of this ability to hold water for extended periods, the study plan focuses on depression wetlands only.

Depression wetlands are single-breach or multiple-breach floodplain wetlands (also called flow-through) based on the number of inlets and/or outlets that exist at elevations above the initial connecting flow. Hedrick et al. (2009) and Bestgen et al. (2011) suggested that there were important differences between these two depression wetland types in terms of entrainment rates, in that flow-through wetlands entrain far greater volumes of water than single-breach types. This study plan proposes examinations of differences between these two wetland types.

Table 2 presents a proposed study matrix to be used as a guide in testing hypotheses (Table 3) associated with the larval trigger. Table 2 identifies key single-breach and flow-through wetlands that should be evaluated. As indicated in Table 2, studies should be implemented over a range of peak flow magnitudes and durations to test the effectiveness of using a larval trigger under a variety of conditions. Flow magnitudes less than 18,600 cfs should be evaluated as suggested in Table 2 because some levees have been breached to allow connection at lower flows and several wetlands (e.g., Stewart Lake) have manually operated inlet gates that allow connection at lower flows.

TABLE 2. Matrix to Be Used in Studying the Effectiveness of a Larval Trigger

Peak Flow (x) as Measured at Jensen, Utah	Proposed Study Wetlands[a, b]	Number of Days (x) Flow to Be Exceeded and Corresponding Hydrologic Conditions [c]		
		$1 \leq x < 7$	$7 \leq x < 14$	$x \geq 14$
8,300 ≤ x < 14,000 cfs	Stewart Lake (f), Above Brennan (f), Old Charley Wash (s)	Dry	Moderately dry	Moderately dry and average (below median)
14,000 ≤ x < 18,600 cfs	Same as previous plus Thunder Ranch (f), Bonanza Bridge (f), Johnson Bottom (s), Stirrup (s), Leota 7 (s)	Average (below median)	Average (below median)	Average (below median)
18,600 ≤ x < 20,300 cfs	Same as previous	Average (above median)	Average (above median)	Average (above median)
20,300 ≤ x < 26,400 cfs	Same as previous plus Baeser Bend (s), Wyasket (s), additional Leota units (7a and 4), Sheppard Bottom (s)	Moderately wet	Moderately wet	Moderately wet
x ≥ 26,400 cfs	Same as previous	Wet	Wet	Wet

(a) f = flow-through wetland, s = single-breach wetland

(b) Up to eight wetlands would be sampled in a given year with the three in the lowest flow category being sampled in all years.

(c) Refer to Table 1 for exceedance percentages and peak flow recommendations for each hydrologic condition. Note that the hydrologic conditions presented are the driest that could support a particular combination of peak flow magnitude and duration. For any combination, wetter hydrology could also support an experiment.

Wetlands that hold the greatest promise for entraining and recruiting razorback suckers, and that are representative of other wetlands in the system should be the focus of studies developed under this plan. Based on discussions with researchers and information presented in Valdez and Nelson (2004), Tetra Tech (2005), Hedrick et al. (2009), and Bestgen et al. (2011), the authors identified candidate study wetlands (Table 2). Because study wetlands connect with the main channel at different flow levels, some can only be studied at higher peak flows (Table 2). Under the study plan, up to eight wetlands would be sampled in a given year with the three in the lowest flow category (Stewart Lake, Above Brennan, and Old Charley Wash) being sampled in all years.

Table 3 summarizes hypotheses, variables to be measured, related studies, and priorities for each. Hypotheses, variables, and related studies are described for each topic in the remainder of this section; priorities are discussed further in Section 3. Additional details on related studies are presented in the Appendix.

TABLE 3. Larval Trigger Study Plan Topics, Hypotheses, Variables, Related Studies, and Priorities

Hypotheses	Variables	Related Studies and Data [(a)]
Topic 1: Entrainment and Retention of Razorback Sucker Larvae in Floodplain Wetlands (Priority: High)		
H_1: Entrainment and retention of larvae in floodplain wetlands are not related to the timing of connecting flows relative to the timing of larval drift (Priority: High)	Timing, duration, and abundance of larvae in the main channel (Priority: High)	Ongoing and expanded project 22f and new floodplain studies (projects FR-164 and FR-165). New modeling effort to predict the timing of larval drift.
	Timing of connecting flows (Priority: High)	New field study needed. Related to ongoing project C6-hydro.
	Volume of water entrained into wetlands during the period of larval drift (Priority: High)	New field study needed. Related to completed project FR-FP synthesis, and ongoing project C6-hydro and flow gage data.
	Larval presence and relative abundance in wetlands after flows recede and connection with the main channel has ended (Priority: High)	Ongoing and expanded project 22f, and new floodplain studies (projects FR-164 and FR-165)
H_2: Entrainment and retention of larvae in floodplain wetlands are not related to the magnitude of connecting flows when larvae are present (Priority: High)	Same as H_1 plus: Magnitude of connecting flows (Priority: High)	Ongoing and expanded project 22f, new floodplain studies (projects FR-164 and FR-165), completed project Cap-6 rz/entr, and ongoing C6-hydro.
H_3: Entrainment and retention of larvae in floodplain wetlands are not related to the duration of connecting flows when larvae are present (Priority: High)	Same as H1 plus: Duration of connecting flows (Priority: High)	Ongoing and expanded project 22f, new floodplain studies (projects FR-164 and FR-165), ongoing C6-hydro, and completed project Cap-6 rz/entr.
H_4: Entrainment and retention of larvae in floodplain wetlands are not related to floodplain wetland characteristics (e.g., single-breach and flow-through, location of wetland, breach/connection elevation) (Priority: High)	Same as H1 plus: Physical characteristics of study wetlands (Priority: High)	New field study needed. Related to ongoing project C6-hydro.
Topic 2: Survival and Escapement of Entrained Razorback Suckers (Priority: High)		
H_1: Relative abundance and condition of YOY razorback suckers in autumn are not related to floodplain wetland characteristics (e.g., single-breach and flow-through, breach/connection elevation, surface area, and depth) (Priority: High)	Relative abundance and condition of YOY suckers in floodplain wetlands in autumn (Priority: High)	Ongoing and expanded project 22f, new floodplain studies (projects FR-164 and FR-165), ongoing efforts at the Stirrup floodplain (projects Cap-6 RZ/recr), and past studies (Cap-6 rz/bt, Cap-6 bt/rz, and data collected in 2011).

Table 3 (Cont.)

Hypotheses	Variables	Related Studies and Data[(a)]
H_2: Relative abundance and condition of age 1 and other razorback suckers at the end of the winter period are not related to floodplain wetland characteristics (Priority: High)	Relative abundance and condition of age 1 and other razorback suckers in floodplain wetlands at the end of winter prior to peak runoff (Priority: High)	New floodplain study (FR-164). Related to the recently completed portion of projects Cap-6 RZ/recr, and past studies (Cap-6 rz/bt, and Cap-6 bt/rz).
H_3: Number of razorback suckers that are able to escape floodplain wetland habitats to the main channel river is not related to floodplain wetland characteristics (Priority: High)	Number of razorback suckers escaping from floodplain wetlands during peak flows (Priority: High)	PIT tag arrays will be deployed at the Stirrup floodplain (Cap-6 RZ/recr) and at Stewart Lake (new study FR-165). Ongoing projects 123a, 123b, 128, 138, and 158 (currently funded through 2012) could detect escaped fish.
	Degree of connection in subsequent years that would provide an opportunity for escapement (Priority: High)	New modeling study needed similar to FR-FP synthesis. Related to recently completed portions of project Cap-6 RZ/recr as well as ongoing deployment of PIT tag array, and ongoing project C6-hydro.
H_4: Floodplain wetlands are not different in terms of surface area, depth, and cover at peak, post-peak, autumn, and end of winter (Priority: High)	Surface area, depth, and cover of floodplain wetlands post-peak, in autumn, and at end of winter (Priority: High)	New field study needed and/or supplement new floodplain studies (FR-164 and FR-165). Related to completed project Cap-6 bt/rz and ongoing project C6-hydro.
H_5: Floodplain wetlands are not different in terms of water quality through the summer and winter (Priority: High)	Water quality in floodplain wetlands through the summer and winter period (Priority: High)	New field study needed, and/or supplement new floodplain studies (FR-164 and FR-165). Related to completed project Cap-6 bt/rz.
Topic 3: Availability of Colorado Pikeminnow Habitat (Priority: Medium)		
H_1: Base flow magnitude is not affected by the use of a larval trigger (Priority: Medium)	Base flow magnitude (Priority: Medium)	Ongoing USGS gage data collection.
H_2: The amount of backwater habitat available for Colorado pikeminnow during the base flow period is not affected by the use of a larval trigger (Priority: Medium)	Surface area, volume, and depth of backwaters at base flow (Priority: Medium)	Ongoing Argonne/Western backwater study.
H_3: The number of Colorado pikeminnow found in backwater nursery habitats in late summer is not affected by the use of a larval trigger (Priority: Medium)	Number of Colorado pikeminnow captured in backwater habitats in late summer/early autumn (Priority: Medium)	Ongoing projects 138 and 158.

Table 3 (Cont.)

Hypotheses	Variables	Related Studies and Data[(a)]
Topic 4: Sediment Mobilization and Channel Maintenance (Priority: Medium)		
H_1: The amount of suspended sediment transport is not affected by the use of a larval trigger (Priority: Medium)	Suspended sediment transport rates (Priority: Medium)	New field study may be needed. Related to completed project 85f.
H_2: Bedload transport is not affected by the use of a larval trigger (Priority: Medium)	Bedload transport rates (Priority: Medium)	New field study may be needed. Related to completed project 85f.
H_3: Channel width and complexity are not affected by the use of a larval trigger (Priority: Medium)	Channel width (Priority: Medium)	New field study needed (aerial photography).
	Channel complexity including the size and number of sandbars that provide backwater habitats (Priority: Medium)	New field study needed (aerial photography).
Topic 5: Fish Community Response (Priority: Low)		
H_1: The diversity and abundance of native and nonnative fish established in floodplain wetlands is not affected by the use of a larval trigger (Priority: Low)	Native and nonnative fish diversity and abundance in floodplain wetlands (Priority: Low)	New field study needed. Related to completed project Cap-6 RZ/recr, Cap-6 rz/bt, and Cap-6 bt/rz.
H_2: The diversity and abundance of native and nonnative fish in main channel habitats is not affected by the use of a larval trigger (Priority: Low)	Native and nonnative fish diversity and abundance in main channel habitats (Priority: Low)	Related to completed project 144, and ongoing projects 123a, 123b, 138, and 158.
	Main channel water temperatures (Priority: Low)	Ongoing water temperature gage data collection.
	Entrainment of burbot through power turbines, bypass or spillway (Priority: High)	Risk Assessment review conducted by NPS, NNF coordinator and Utah.

(a) Ongoing and completed projects are described in the Appendix.

Topic 1: Entrainment and Retention of Razorback Sucker Larvae in Floodplain Wetlands

Topic 1 addresses factors that may affect entrainment and retention of larval razorback suckers in floodplain wetlands. Included under this topic is an examination of the role of peak flow characteristics (e.g., timing, magnitude, and duration of connecting flows relative to the timing of larval drift) and floodplain wetland characteristics (e.g., single-breach and flow-through, location of wetland, breach/connection elevation) in relation to the entrainment and

retention of razorback sucker larvae in floodplain wetlands. To evaluate this topic, peak releases and connecting flows would be timed to coincide with the presence of larvae, but there could be significant variation in abundance during the peak release period. Data collected for this portion of the study would be compared to historical data (i.e., Bestgen et al. 2011) collected when the Yampa River trigger was used.

Hypotheses[2] to be tested under Topic 1 include:

H_1: Entrainment and retention of larvae in floodplain wetlands are not related to the timing of connecting flows relative to the timing of larval drift.

H_2: Entrainment and retention of larvae in floodplain wetlands are not related to the magnitude of connecting flows when larvae are present.

H_3: Entrainment and retention of larvae in floodplain wetlands are not related to the duration of connecting flows when larvae are present.

H_4: Entrainment and retention of larvae in floodplain wetlands are not related to floodplain wetland characteristics (e.g., single-breach and flow-through, location of wetland, breach/connection elevation).

To test hypotheses for Topic 1 (Table 3), a variety of data should be collected, and some data will be useful for testing more than one of the hypotheses listed above. Data needs, related existing studies, and, where applicable, the need for new studies are presented next. Although separate hypotheses are considered for the potential effects of timing, magnitude, and duration of flows, it may be difficult to separate the effects of these variables since they can effect entrainment both collectively and individually.

- *Timing, duration, and abundance of larvae in the main channel*. Ongoing project 22f would be used to gather these data. Bestgen et al. (2011) also suggested that it may be possible to develop relationships based on physical attributes (e.g., water temperature and time of year) to predict the timing of larval drift. Such modeling would be useful for operational planning and should be developed and used to predict the first occurrence of larvae, but should not replace direct measurements of drift to test this hypothesis.

- *Timing, magnitude, and duration of connecting flows*. A new field study would be needed to collect these data, but could tier from ongoing project C6-hydro to assess actual connection flow (i.e., when river flow begins to enter wetlands) at each study wetland at the beginning of the study, and perhaps every year thereafter until study completion. It may be necessary to develop new river flow and entrainment relationships at the beginning of the study, and periodically during the study, if breach elevations are altered by annual high flows. Green River researchers have noted the poor concordance between published (i.e., Valdez and Nelson 2004; Bestgen et al. 2011) connecting flows and actual connecting flows following high-flow years. These differences between actual and

[2] All hypotheses are written as null hypotheses, i.e., that there is no effect or difference between the elements compared.

published connecting flows may be especially noticeable following the very high flows in 2011. Thus, it would be important to assess breach condition and elevations prior to spring peak flow in 2012, if possible.

- *Volume of water entrained into wetlands during the period of larval drift*. Data collected to determine connection flows, flow gage data, and the relationships developed by Bestgen et al. (2011) should be used to determine annual water volume entrained into wetlands. The relationships used may need to be modified annually or occasionally if breach elevations are altered by annual high flows.

- *Larval presence and abundance in wetlands after flows recede and connection with the main channel has ended*. Modifications to existing project 22f and new studies by UDWR and USFWS in floodplain wetlands will provide sampling needed to inform this information need. Those studies follow aspects of sampling protocols used in 2011 to evaluate larval presence in floodplain wetlands. Based on experience in 2011, it may be difficult to accurately assess the presence and abundance of larvae in wetlands after flows recede. This is at least partly a result of the large size of some of the study wetlands, sampling effort, and the number of larvae entrained. For this reason, it is recommended that even if larvae were not detected initially in study wetlands, these wetlands be sampled again before the subsequent spring peak to determine if razorback suckers had been entrained. Abundance estimates should be quantified to the extent possible, but may need to rely on effort-based estimates or estimates of relative abundance. In addition, a research project using marked individuals (e.g., Hedrick et al. 2009) could be used to better quantify abundance of larvae in light trap samples and calibrate sampling effort and results accordingly. *Physical characteristics of study wetlands. Important physical characteristics of study wetlands include (1*) number of inlets/outlets, (2) breach/connection elevations, and (3) distance from spawning areas. Some of the physical characteristics of potential study area wetlands are well known (e.g., number of inlets/outlets and distance from spawning areas), but, as mentioned above, breach/connection elevations should be assessed initially and annually if possible following protocols in project C6-hydro.

Topic 2: Survival and Escapement of Entrained Razorback Suckers

Topic 2 addresses factors that may affect the survival of razorback suckers entrained as larvae into floodplain wetlands and their eventual escapement from those wetlands into the main channel of the river. Survival of larvae and eventual escapement of subadults are essential elements of the razorback sucker life cycle (e.g., Muth et al 2000.). Entrainment into wetlands that cannot support razorback suckers through at least one and potentially several years provides no benefit to the species, and could have a negative effect if these wetlands functioned as sinks from which suckers could not re-enter the main channel. Studies would focus on evaluating the abundance and condition of YOY and subadult fish as related to floodplain wetland characteristics that could affect their suitability to serve as nursery and overwinter habitats, while also allowing escapement to the main channel. Wetland characteristics to evaluate under Topic 2 include floodplain wetland type (e.g., the number of connections (single-breach vs. flow-through), breach/connection elevation, surface area, depth, cover, and water quality, particularly

temporal patterns of dissolved oxygen. When evaluating each study wetland, there should be consideration of whether or not the wetland had been reset in previous years (i.e., drained or dried sufficiently to eradicate nonnative resident fish). Note that the relative abundance of YOY will also depend on entrainment rates, and, therefore, testing the hypotheses of Topic 2 will require controlling for previous entrainment rates.

Hypotheses to be tested under Topic 2 include:

H_1: Relative abundance and condition of YOY razorback suckers in autumn are not related to floodplain wetland characteristics (e.g., single-breach and flow-through, breach/connection elevation, surface area, depth, and cover).

H_2: Relative abundance and condition of age 1 and other razorback suckers at the end of the winter period are not related to floodplain wetland characteristics.

H_3: Number of razorback suckers that are able to escape floodplain wetland habitats to the main channel is not related to floodplain wetland characteristics.

H_4: Floodplain wetlands are not different in terms of surface area, depth, and cover at peak, post-peak, autumn, and end of winter.

H_5: Floodplain wetlands are not different in terms of water quality through the summer and winter.

To test hypotheses for Topic 2 (Table 3), a variety of data should be collected. Data needs, related existing studies, and, where applicable, the need for new studies are presented next.

- *Relative abundance and condition of YOY suckers in floodplain wetlands in autumn*. Two new studies conducted by USFWS (project FR-164) and UDWR (project FR-165), which will sample floodplain wetlands in the post-connection period, and an expanded project 22f have been funded to accommodate these data needs. Other related projects that have been completed, but that could be tiered from include Cap-6 RZ/recr, Cap-6 rz/bt, and Cap-6 bt/rz. Abundance estimates should be quantified to the extent possible, but may need to rely on effort-based estimates. Condition of individual fish should be based on calculations of relative weight or length-weight relationships; otherwise, qualitative assessments of condition should be recorded.

- *Relative abundance and condition of age 1 and other razorback suckers in floodplain wetlands at the end of winter prior to peak runoff*. Two new studies conducted by USFWS (project FR-164) and UDWR (project FR-165), which will sample floodplain wetlands in the post-connection period, and expanded project 22f have been funded to accommodate these data needs. Sampling will be similar to that conducted in autumn. .

- *Number of razorback suckers escaping from floodplain wetlands during peak flows*. To gather these data, a new study would be needed that tags fish captured in autumn and pre-peak spring samples using Passive Integrated Transponder (PIT) tags and uses PIT tag

antenna arrays in breaches and points of connection to determine escapement. These studies will complement other tag-recapture studies including projects 123a, 123b, and 128, and the new floodplain studies (projects FR-164 and FR-165). This study could tier from completed project Cap-6 RZ/recr. In addition, an evaluation of recaptures in subsequent years in ongoing main-channel sampling (e.g., projects 123b, 128, and 138) would provide information on the ultimate fate of fish escaping from floodplain wetlands.

- *Degree of connection in subsequent years that would provide an opportunity for escapement*. A post-hoc evaluation of escapement opportunity would be conducted using gage-based estimates of river elevation, previously derived estimates of breach/connection elevation, and previously reported fish passage criterion (Burdick 1997) to determine the duration of escapement opportunity in any given year.

- *Surface area, depth, and cover of floodplain wetlands post-peak, in autumn, and at end of winter*. To gather these data, a new study would be needed, possibly as an expansion of project C6-hydro or Cap-6 bt/rz. The purpose of this study would be to gather information on the physical characteristics of floodplain wetlands that are most important in determining the ability of floodplain wetlands to provide for survival and escapement of razorback suckers. Although detailed survey-grade quantification of surface area and depth would be of greatest value, less detailed information, if representative and unbiased, could be gathered and used instead.

- *Water quality in floodplain wetlands through the summer and winter period*. Eutrophication during the summer and a reduction in free water in the winter could result in a reduction in dissolved oxygen levels in floodplain wetlands that affect fish health and survivorship. A new study would be needed to monitor water quality through summer and winter and should focus on critical periods when water quality is considered potentially limiting. The study could tier from completed project Cap-6 bt/rz.

Topic 3: Availability of Colorado Pikeminnow Habitat

It is possible that using a larval trigger could have consequences on other components of the Green River ecosystem. Topic 3 addresses the effect of using a larval trigger on base flows and Colorado pikeminnow nursery habitats. As mentioned in Bestgen et al. (2011), using a greater release volume to meet peak-flow targets could result in less water available for base flows, and, consequently, less Colorado pikeminnow nursery habitat through the summer and autumn. The analysis of this topic would include a comparison of new data and historical data.

Hypotheses to be tested under Topic 3 include:

H_1: Base flow magnitude is not affected by the use of a larval trigger.

H_2: The amount of backwater habitat available for Colorado pikeminnow during the base flow period is not affected by the use of a larval trigger.

H_3: The number of Colorado pikeminnow found in backwater nursery habitats in late summer is not affected by the use of a larval trigger.

Data needs, related existing studies, and, where applicable, the need for new studies (e.g., Table 3) to address these hypotheses are presented next.

- *Base flow magnitude.* Flows during the base flow period as measured at the Jensen gage would be used in this analysis. Comparisons would be made to historical data collected in years with comparable hydrology when a larval trigger was not used.

- *Surface area, volume, and depth of backwaters at base flow*. These data would be collected as part of the ongoing backwater topography and modeling project conducted annually by Argonne National Laboratory and Western Area Power Administration. Comparisons would be made to historical data collected in years with comparable hydrology when a larval trigger was not used.

- *Number of Colorado pikeminnow in backwater habitats in late summer*. Ongoing project 138 and perhaps project 158 (ongoing through 2012 and perhaps beyond) would be used to determine effort-based catch rates of YOY Colorado pikeminnow. Comparisons would be made to historical data collected in years when a larval trigger was not used.

Topic 4: Sediment Mobilization and Channel Maintenance

It is possible that using a larval trigger could have consequences on other components of the Green River ecosystem. Topic 4 addresses the effect of using a larval trigger on sediment mobilization and channel maintenance. Using a larval trigger could result in an overall reduction in annual peak flow magnitude in the middle Green River, because Flaming Gorge releases would not coincide with and add to Yampa River flows. This reduction in peak flow magnitude in this reach could result in less sediment transport and channel maintenance. It is also possible that using a larval trigger could result in longer peak-flow duration in this reach, but lower magnitude peaks that affect erosion and deposition patterns.

Hypotheses to be tested under Topic 4 include:

H_1: The amount of suspended sediment transport is not affected by the use of a larval trigger.

H_2: Bedload transport is not affected by the use of a larval trigger.

H_3: Channel width and complexity are not affected by the use of a larval trigger.

Data needs, related existing studies, and, where applicable, the need for new studies (see Table 3) to address these hypotheses are presented next.

- *Suspended sediment transport rates*. Collection of these data would require a new study or renewal of elements of the recently completed project 85f, but it may be possible to

use existing sediment transport equations from project 85f to estimate suspended sediment transport under different flow conditions.

- *Bedload transport rates*. Similar to the previous variable, collection of these data would require a new study or renewal of elements of the recently completed project 85f, but it may be possible to use existing sediment transport equations from project 85f to estimate bed load sediment transport under different flow conditions.

- *Channel width*. Collection of these data would require a new study that builds on existing aerial photography

- *Channel complexity, including the size and number of sandbars that provide backwater habitats*. Similar to the previous variable, collection of these data would require a new study that builds on existing aerial photography.

Topic 5: Fish Community Response

It is possible that using a larval trigger could have consequences on other components of the Green River ecosystem. Topic 5 addresses the effect of using a larval trigger on native non-endangered fishes, particularly co-evolved catostomids, and nonnative fish populations in floodplain wetlands and in the main channel. Using a larval trigger could result in a positive response by other native fishes as well as nonnative fishes, at least in part because annual peak flows that are thought to suppress nonnative fish populations may be lower if a larval trigger is used. The risk of entraining nonnative burbot (*Lota lota*) through power turbines, bypass tubes, or spillway has not been assessed and may increase with increased use of bypass during peak releases. These analyses would include a comparison of new data and historical data.

Hypotheses to be tested under Topic 5 include:

H_1: The diversity and abundance of nonnative fish established in floodplain wetlands is not affected by the use of a larval trigger.

H_2: The diversity and abundance of nonnative fish in main channel habitats is not affected by the use of a larval trigger.

Data needs, related existing studies, and, where applicable, the need for new studies (Table 3) to address these hypotheses are presented next.

- *Native and nonnative fish diversity and abundance in floodplain wetlands*. Two new studies conducted by USFWS (project FR-164) and UDWR (project FR-165), which will sample in floodplain wetlands in the post-connection period, and expanded project 22f have been funded to partially accommodate these data needs. Data collection will include fishes captured and measures of relative abundance (catch per unit effort [CPUE]) in floodplain wetland habitats. The study could tier from completed projects Cap-6 RZ/recr, Cap-6 rz/bt, and Cap-6 bt/rz.

- *Native and nonnative fish diversity and abundance in main channel habitats*. These data are being collected under ongoing projects 123a, 123b, 138, and 158 (at least through 2012).
- *Entrainment of burbot through power turbines, bypass tubes or spillway.* A literature review, and risk assessment will be completed by the NPS, Utah, and the Nonnative Fish coordinator in 2012.
- *Main channel water temperatures*. Existing water temperature gages would be used to monitor main channel temperature through the year. Comparisons would be made to historical data collected in years with comparable hydrology when a larval trigger was not used.

3 RESEARCH PRIORITIES AND IMPLEMENTATION

As described in Section 2, five topics are included in this study plan: (1) entrainment and retention of larval razorback suckers in floodplain wetlands; (2) survival and eventual escapement of entrained larvae in floodplain wetlands; (3) availability of Colorado pikeminnow habitat; (4) sediment mobilization and channel maintenance; and (5) fish community response. Studies associated with Topics 1 and 2 are considered the highest priority because these studies address the objectives of using a larval trigger (i.e., razorback sucker entrainment and recruitment). Topics 3, 4, and 5 address potential other consequences of using a larval trigger, and are considered lower priority. It is important to note that the priorities assigned to topics in this study plan are relative to their importance to testing the effectiveness of implementing a larval trigger and not to overall priorities of the Recovery Program. Studies identified as low priority here could be high priority for other Program elements.

Table 3 summarizes hypotheses, variables to be measured, related studies, and priorities for each topic addressed in the study plan. Overall priorities are categorized as high, medium, or low based on the perceived relationship between the topic and the larval trigger, and the importance of the information in understanding that relationship and testing specific hypotheses.

Within topics, certain hypotheses and variables are considered higher priority than others (Table 3). For Topic 1, all hypotheses and variables are considered high priority and essential for interpretation of the effectiveness of the larval trigger in achieving recovery of razorback suckers. For Topic 2, obtaining useful information on abundance and condition of fish in both the autumn and after the winter period prior to peak runoff is considered high priority. Numbers and condition in autumn would be useful for determining survival and growth during the summer, and could be used to interpret pre-peak numbers, but only winter data would enable a determination of the usefulness of wetlands for completing the cycle from entrainment to escapement. It is considered a high priority to measure the opportunity for escapement, but direct measurements of escapement using a PIT tag antenna array may be considered on an as-needed basis. Escapement should also be inferred from captures of wild-spawned subadults or adults in the main channel during ongoing survey projects (e.g., 123b and 138). Under Topic 2, measurements of wetland surface area and depth are considered most important at times when these variables would be at their minimum (i.e., limiting) values (e.g., at the end of the summer). Water quality data are considered high priority, because this information is relatively easily obtained and could be used to identify issues that could limit the value of floodplain wetland habitats.

The remaining topics are considered to be medium (Topics 3 and 4) or low (Topic 5) priority for purposes of testing the effectiveness of the larval trigger. These topics were identified in the Green River study plan (Green River Study Plan *ad hoc* Committee 2007) and will be evaluated as part of that process. Topic 3 would be evaluated using field data collected annually under existing ongoing projects. Thus, even though the topic is considered to be medium priority for this study plan, it could be evaluated with minimal new or additional work, and it is recommended that this topic be evaluated. Topic 4 would require potentially expensive new field studies to measure sediment transport (unless transport relationships developed in project 85f could be used to estimate transport under different flow regimes), and collect aerial photography.

Topic 5 is considered low priority for this study plan, but ongoing studies would provide much of the data needed to test relevant hypotheses. To further evaluate the effects of using a larval trigger, Reclamation will conduct a retrospective analysis of dam release hydrographs that may have occurred since 2006 if the larval trigger had been implemented along with existing peak- and base flow objectives specified in the 2006 Record of Decision. This modeling will be used primarily by the Flaming Gorge Technical Work Group to inform their flow planning process in future years.

As practicable, proposed studies should address the flow magnitude and duration bins shown in Table 2, but three years with flows < 18,600 cfs and three years with flows $\geq$ 18,600 cfs and with connecting flows in each of these years of at least seven days duration are considered necessary to complete the study. Although it could be possible to complete the study in six years, ultimately the length of the study will be dependent on annual hydrologic conditions. Figure 1 shows a decision tree to be used when determining the need for monitoring actions in any given year.

Under the study plan, up to eight wetlands would be sampled in a given year. Only wetlands that are thought to hold the greatest promise for recruiting razorback suckers and that are representative of other wetlands in the system should be chosen for study (see Table 2 for wetlands identified as candidates for study). Some additional evaluation may be needed prior to selecting study wetlands to verify the flows at which wetlands connect to the main channel, and to determine their suitability as nursery habitat. In order to make meaningful statistical inferences from the data, it will be important to study the same wetlands each year to the extent possible.

The specific objectives, tasks, and expected outcomes for individual studies developed under this plan will be identified in statements of work approved by the Recovery Program. These projects and the resulting project reports will go through the standard Recovery Program review protocols. It is anticipated that a synthesis report will be developed that summarizes results from individual projects, integrates results, summarizes conclusions, and makes recommendations for future implementation of a larval trigger.

As for any study plan, additional knowledge will be gained during implementation, and it will be important to have enough flexibility to adjust studies and overall approaches in response to this new information. Emerging data gaps regarding the relative effects of flow magnitude, duration and timing on larval entrainment should also help guide the direction of research. The topics, hypotheses, variables, and priorities presented here are a starting point, rather than a fixed path forward.

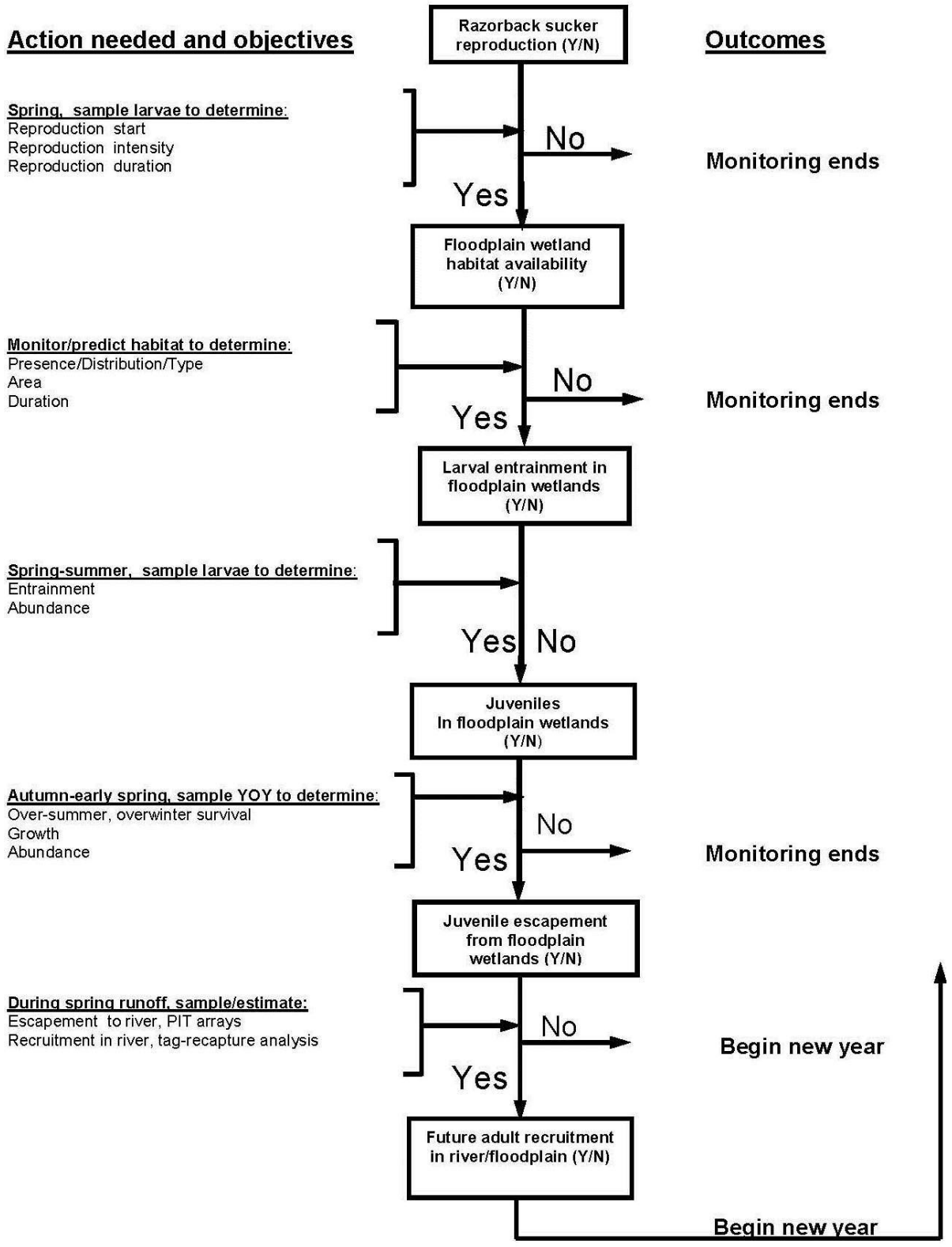

FIGURE 1. Monitoring Decision Tree to Be Used in Evaluating the Larval Trigger

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APPENDIX

RECOVERY PROGRAM PROJECTS RELATED TO THIS STUDY PLAN

TABLE A-1. Ongoing and Completed Recovery Program Studies Identified in Table 3 and in the Text that Will Contribute Information to Hypotheses Testing.

Project No.	Project Title[(a)]	Comments
22f	Interagency Standardized Monitoring Program (ISMP) assessment of endangered fish reproduction in relation to Flaming Gorge Dam operations in the middle Green and lower Yampa Rivers.	Long-term (since 1992) standardized main channel light trapping for larval razorback suckers, which will provide real time information to trigger Reclamation's experimental operations. Study was expanded to incorporate larval sampling in floodplain habitats. Addresses Topic 1 hypotheses.
FR-164	Middle Green River floodplain sampling.	New study in 2012 (complements larval sampling covered in project 22f). Sample wetlands in spring to determine overwinter survival of razorback sucker; qualitatively describe fish community in wetlands; document entrainment and recruitment of razorback sucker in fall; collect water quality information at wetlands. Addresses Topic 1 and 2 hypotheses.
FR-165	Use of the Stewart Lake floodplain by larval and adult endangered fishes	New study in 2012. Monitor entrainment of larval endangered fishes during high flows; examine fish community composition and habitat characteristics post floodplain connection; monitor escapement of native and nonnative fishes from Stewart Lake. Addresses Topic 1 and 2 hypotheses.
C-6 hydro	Physical evaluation of floodplain habitats restored/enhanced to benefit endangered fishes of the Upper Colorado River basin.	This ongoing study will need to be revised to address study plan information needs at floodplain habitats in Green River subbasin. Addresses Topics 1 and 2 hypotheses.
FR-FP synthesis	Synthesis of flood plain wetland information.	Completed study, which serves as a basis for the Larval Trigger Study Plan. Addresses Topic 1 hypotheses. Results summarized in Bestgen et al. (2011).
Cap-6 rz/entr	Entrainment of larval razorback sucker.	Completed study, which serves as a basis for the Larval Trigger Study Plan. Addresses Topic 1 hypotheses. Results summarized in Hedrick et al. (2009).
C-6	Green River Subbasin Floodplain Management Plan.	Completed study, which provides background information related primarily to Topic 2 hypotheses. Results summarized in Valdez and Nelson (2004).
Cap-6 rz/bt	Larval razorback and bonytail survival in Baeser.	Completed study, which provides background information related primarily to Topic 2 hypotheses. Results summarized in Brunson and Christopherson (2005). Larval razorback sucker and bonytail survival and growth in the presence of nonnative fish in the Baeser floodplain wetland of the middle Green River.

Table A-1 (Continued)

Project No.	Project Title[(a)]	Comments
Cap-6 bt/rz	Larval bonytail and razorback sucker survival in floodplain habitats.	Completed study, which provides background information related primarily to Topic 2 hypotheses. Results summarized in Modde and Haines (2005). Survival and growth of stocked razorback sucker and bonytail in multiple floodplain wetlands of the middle Green River under reset conditions.
Cap-6 RZ/recr	Razorback sucker survival and emigration from the Stirrup floodplain	Research aspects of this study have been completed: Hedrick et al. (2012). Razorback sucker survival and emigration from the Stirrup floodplain, Middle Green River, Utah 2007-2010. UDWR will continue to deploy a PIT tag array during floodplain connection and monitor/augment water quality as needed at the Stirrup floodplain in 2012 and beyond. Primarily addresses Topic 2 hypotheses.
128	Abundance estimates for Colorado pikeminnow in the Green River Basin, Utah and Colorado	These ongoing efforts comprise many hours of main channel electrofishing, which can detect razorback suckers escaping from floodplains, i.e. Topic 2 hypotheses. Projects 123(a) and (b) can also evaluate changes in main channel fish community, i.e. address Topic 5 hypotheses.
123b	Nonnative fish control in the middle Green River	
123a	Nonnative Fish Control in the Echo Park to Split Mountain Reach of the Green River, Utah	
138	Annual fall monitoring of YOY Colorado pikeminnow and small-bodied native fishes.	This ongoing study provides a long term assessment of the small bodied fish community in backwater habitats throughout the middle Green River. Addresses Topic 3 hypotheses
144	Green River native fish response to nonnative control	Completed study, which provides background information related primarily to Topic 5 hypotheses. Draft report in review.
158	Assessment of larval Colorado pikeminnow presence and survival in low velocity habitats in the middle Green River	Ongoing study with final year of field work scheduled in 2012 (may be extended). Verify that larval pikeminnow are arriving in nursery habitat; document abundance of larval Colorado pikeminnow in backwaters as season progresses; determine success of removing and excluding nonnative fish from backwaters using various blocking techniques and depletion treatments; assess small-bodied fish community effects from removing nonnative fishes from backwaters. Addresses Topic 3 and 5 hypotheses.
FR-BW synthesis	Historical assessment of factors affecting young Colorado pikeminnow abundance and physical habitat availability in the Green River, Utah.	This synthesis (in preparation) incorporates long-term age-0 pikeminnow collection data (e.g., project 138) and sandbar topography (Argonne National Laboratory) to describe physical and biological habitat responses to middle Green River flows. Provides a baseline for Topics 3 and 4 hypotheses.

Table A-1 (Continued)

Project No.	Project Title[(a)]	Comments
85f	Gunnison and Green River sediment monitoring	Completed study, report in final revision; sediment transport equations could be used to address Topic 4 hypotheses. Results presented in Williams et al. (2011). Application of Sediment Characteristics and Transport Conditions to Resource Management in Selected Main-Stem Reaches of the Upper Colorado River, Colorado and Utah, 1967–2007.
FR-115	Monitoring effects of Flaming Gorge Dam releases on the Lodore/Whirlpool fish community	This ongoing fish community monitoring study will provide some evaluation of effects of Reclamation's releases to meet the larval trigger in upstream reaches. Addresses Topic 5 hypotheses.

(a) Full scopes of work are available at: http://www.coloradoriverrecovery.org/documents-publications/work-plan-documents/project-scopes-of-work.html#I. Completed studies are available at: http://www.coloradoriverrecovery.org/documents-publications/technical-reports/habitat-restoration.html.