Summary of Current Rio Grande Silvery Minnow Habitat Restoration Design and Application

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Abstract

Due to population decline and reduction of historical habitat range, the Rio Grande Silvery Minnow (silvery minnow) is a Federal and State listed endangered species. Currently the silvery minnow populations inhabit approximately 10 percent of their historical range. Declining silvery minnow population is attributed to the geomorphic and habitat effects resulting from: 1) upstream dam, levee and diversion dam construction, 2) river channelization, 3) effects of water withdrawals on river flows, and 4) changing climate. Habitat restoration has been undertaken to protect and improve the status of the silvery minnow while simultaneously protecting existing and future regional water uses.

The purpose of this paper is to review, summarize, and briefly evaluate the types of habitat restoration projects implemented on the Middle Rio Grande, in terms of their site selection, design criteria, and supporting analysis. We include the latest information on silvery minnow ecology, habitat, and food source needs which informs habitat restoration planning and design. Morphological changes on the Middle Rio Grande include channel narrowing, incision and disconnection of the main channel from its historical floodplain, habitat fragmentation, and channel width and depth homogeneity. Ecological and project specific design criteria, habitat restoration methods and limitations, site and technique selection, design analysis, and post project silvery minnow use, and general channel response are described. Habitat restoration has often involved lowering floodplain and channel features to provide spawning and rearing habitat. Suspended sediment is deposited on lowered floodplain and channel surfaces reducing their design life. We describe preliminary available information on project effectiveness and sustainability such as habitat usage, and channel response. We close by discussing monitoring and post project evaluation needed to provide vital information on sustainability for effective planning and implementation of additional habitat restoration.

Introduction

The decline of native fish communities, even past extirpation of indigenous species, has been well-documented (Platania 1991). Because of population decline and reduction of historical habitat range, the Rio Grande silvery minnow (silvery minnow) is a Federal and State (New Mexico and Texas) listed endangered species (Federal Register [FR] 1994; New Mexico Department of Game and Fish [NMGF] 1996). Currently the silvery minnow populations inhabit approximately 10 percent of the historical range (Bureau of Reclamation [Reclamation] 2015).

Declining silvery minnow populations are generally attributed to the geomorphic and habitat effects of: 1) upstream dam, levee and diversion dam construction, 2) river channelization, and 3) effects of water withdrawals on river flows (Bestgen and Platania 1991; Swanson et. al. 2011). Ideally, diverse and suitable riverine habitat would be accomplished by the channel dynamics of fluvial erosion and depositional processes using the available sediment and hydrology. However, both sediment supply and peak flows have been reduced due to upstream reservoir construction (Jemez Canyon, Cochiti, Galesteo Creek, and Abiquiu Dams) resulting in the loss historical channel dynamics. The Middle Rio Grande Endangered Species Collaborative Program (MRGESCP) was created to protect and improve the status of the listed species (Tetra Tech 2004) while simultaneously protecting existing and future regional water uses. Many habitat restoration projects have been undertaken by the MRGESCP on the Middle Rio Grande. The primary purpose of this report is to review, summarize and briefly evaluate site selection, design criteria and analysis for habitat restoration projects on the Middle Rio Grande by the MRGESCP and by Reclamation.

A focused literature review of silvery minnow ecology, habitat, and food source needs is included to provide the latest knowledge for site selection and habitat restoration design. There is a considerable amount of published information documenting the need for restoration, site selection, habitat needs and environmental compliance. Some preliminary but not conclusive information is available on project effectiveness and sustainability.

Rio Grande Silvery Minnow Biology and Habitat Needs

Biology

Silvery minnows produce numerous semi-buoyant non-adhesive eggs typical of the genus *Hybognathus*. (Platania and Altenbach 1998, Platania 2000). Most spawning occurs during the spring runoff peaks during the months of May and June when water temperature generally exceeds 18-24˚ C (64 to 75˚ F) (Dudley and Platania, 1997). The minimal magnitude of flow peak necessary to stimulate spawning is not well defined. A 24-hour flow increase from about 430 cfs to about 1,200 cubic feet per second (cfs) on May 19, 1996, apparently stimulated a spawning event (Tetra Tech, 2014). As such, "spring runoff peak flows that overbank the floodplain and creates seasonally important larval habitat in May and June are strongly correlated with higher silvery minnow density as measured in the fall" (FWS 2013).

Semi-buoyant eggs have been observed to drift until they are entrained in low-velocity habitats (e.g., backwaters, channel edges and inundated bars and floodplains), or hatch about 24 to 72 hours post fertilization depending on water temperature (Platania 1995, 2000; Reclamation 2015). Newly hatched larvae are observed to passively drift for another approximately 3 days until their air bladders develop whereupon they are thought to actively seek low-velocity habitats (Platania and Altenbach 1998; Medley and Shirey 2013). River channels that are entrenched and narrowed due to reduction in sediment load and flood peaks have disconnected floodplains that offer minimal low velocity floodplain habitat for egg/larval retention. These conditions "exacerbate the likelihood that newly spawned eggs and hatching larvae will remain continuously exposed to strong river currents, minimizing their potential survivorship" (Tetra Tech 2014). Both the spawning and egg drift indicate that floodplain connectivity is a primary need for population recruitment.

Research by Shirey (2004) and Cowley et al., (2006) have shown that silvery minnow consumes diatoms largely found in soft fine sediment substrate. In addition to diatoms, other primary food sources appear to be algae and small invertebrates (Shirey et al. 2008). Most available algae and diatoms for silvery minnow consumption are believed to occur in low velocity habitats, in vegetated lateral zones – i.e., areas with emergent vegetation, backwater or slackwater areas and along bank lines especially with overhanging vegetation (FWS 2010).

Habitat Needs

In general, the species is most often found in low velocity and low depth habitat with silty and sandy substrate with suitable temperatures and nearby available food supply. Habitat criteria for adults includes flow depths less than 60 cm (2.0 ft.) and velocities less than 40 cm/s (1.3 ft./s), while juveniles require flow depths less than 50 cm (1.6 ft.), and velocities less than 30 cm/s (1.0 ft./s). Larvae habitat is less than 5 cm/s (.16 ft./s) velocity and less than 15 cm (o.5) flow depth. "Shallow areas in the floodplain during inundation and recession produce habitats with increased water temperatures which promotes improved local food availability and subsequently faster larval growth rates" (Mortensen, et al., 2019). Thus, the best main channel and floodplain (off channel) habitat for silvery minnows include areas that have a diversity of connected, relatively low-velocity flows with shallow depths.

Habitat Design Criteria

Ecological Criteria

Design criteria are centered on habitat needs of the silvery minnow. The FWS (2010) has determined that the silvery minnow habitat needs include backwaters, shallow wide channels, pools, and varying depth and velocity habitat all of which are necessary for each of the particular life history stages in the appropriate seasons. They identify that eddies created by debris piles, pools, backwaters or other refugia habitat provide a wide range of depth and velocities. Low velocity areas of sand and silt substrate in proximity to bank lines have been shown to provide food sources (FWS 2003; FWS 2010; Scholle 2015). Specific habitat needs organized by life history and seasons are summarized by Baird (2016) and Mortensen et al. (2019):

- Spawning and egg retention (April-June). The primary concern during spring runoff is having suitable conditions to produce eggs and provide for retention and development of eggs and larvae. High flows to create river-floodplain connectivity, and during low flow years low velocity and flow depth areas in the main channel are needed.
- Larval and juvenile development (June-October). This season usually produces beneficial main channel conditions due to the warm temperatures and low flows, but river drying imposes a severe threat to the silvery minnow in the contemporary environment.
- Over-wintering (November-March). Low velocity areas less than 1.3 ft./s and depths less than 1.5 ft. These are the characteristics of the most commonly occupied habitats, while habitat for the feeding and development is about the same depth (1.5 ft./s) but slower velocity on the order of 0.5 ft./s. Having areas of reduced velocity to reduce energy demands as well as providing areas of refuge from predation (SWCA 2008; FWS 2010) are often provided by in-stream debris piles.
- Adult (year round). Increased flow to support spawning between April 15 and June 15. Deeper and cooler habitat to act as refugia during drought periods, and plentiful food

supply, refuge from predation, and shading to escape higher summer water temperatures.

River Flow Criteria

For design purposes, the above flow depth, velocity and food sources need correlation to flow rates and flow durations for lateral river-floodplain connectivity to benefit reproduction and larval development. Due to flow variability, creating connectivity surfaces that inundate under a range of suitable flows is necessary. FWS (2013) developed a working hypothesis to correlate the magnitude of the spring runoff peak, peak flow duration, and the duration of overbank flooding with average silvery minnow population densities observed in the fall (October). Higher magnitude spring flows with longer peak flow and overbank flow duration results in more silvery minnows in the fall population surveys (Tables 1 and 2). The Coefficient of Determination for the relationships in Table 1 and Table 2 are about 0.78.

Table 1. Correlated Relationship between Spring Runoff Peak Flow Magnitude and Average Silvery Minnow Density Observed in the Fall (FWS 2013)

Discharge (cfs)	Approximate Fall Population/100m^2(1080 ft^2)
1,600	~ 1.5 silvery minnow
2,000	~3.0 silvery minnow
3,750	~5.0 silvery minnow

Table 2. Correlated Relationship between the Duration of Overbank Flooding (days of peak discharge > 2,500 cfs at the USGS Central Bridge Gage) and average Silvery Minnow Density Observe in the Fall (FWS 2013).

Duration of Peak Flow > 2,500 cfs	Approximate Fall Population/100m^2 (1080 ft^2)
13	~1.5 silvery minnow
28	~3.0 silvery minnow
41	~5.0 silvery minnow

MEI (2006b) reported that based on experience in the reach near Albuquerque, NM, 25 days (6.8 percent exceedance value on the mean daily flow duration curve) of floodplain inundation provides for optimum egg retention and larval recruitment. In this reach the 25-day exceedance flow is about 4,000 cfs. Thus, floodplain surfaces that inundated at or below 4,000 cfs would provide suitable lateral floodplain connectivity. This does not account for the risks associated with drier flow years where spring flows do not reach those levels. To address this risk MEI (2006b) divided the annual flow volumes into dry, normal and wet years. 25-day exceedance values from dry, normal and wet year flow duration curves were 1,400, 3,500, and 5,600 cfs respectively. In summary, creating surfaces with lateral floodplain connectivity that are inundated during spring runoff for a minimum number of days benefits silvery minnow reproduction and larval development. Given the risk associated with hydrologic variability and potential temporal and spatial changes in riverbed elevation, creating surfaces that are inundated under a range of suitable flows is necessary. The minimum flow ranges used for site selection and design appear to be somewhere between 1,500 and 2,000 cfs (Tetra Tech 2014;

FWS 2013). Since 2014 there has been an emphasis on creating surfaces inundated at lower discharges corresponding to low flow years when few silvery minnows' are sampled (Posner, 2019). Using the probability of May-June flows for low flow years with corresponding low populations of silvery minnows, it was determined that the 50% exceedance design discharge was about 300 cfs. Surfaces excavated for construction design for inundation at about 300 cfs will be inundated more frequently than sites with higher design discharges and will also experience more sediment deposition.

The habitat value of connected surfaces can be enhanced by adding secondary channels and embayments within lowered areas to create more bankline habitat and associated food sources. Excavating or otherwise creating locally irregular bank lines upstream and downstream near restoration projects also provides food sources and local cover. In addition, including large wood at restoration projects increases availability of overwintering habitat with increased source of food.

Habitat Restoration Techniques and Lessons Learned

Ideally, restoration would be accomplished by the channel dynamics of fluvial erosion and depositional processes using the available sediment and hydrology to promote bars, islands, backwaters, slack waters, complex channel edge habitat, and floodplain connectivity. The extensive native and non-native vegetation on the bars has provided root structure which precludes redistribution of sediment observed during flows like the long-duration, high flows in 2005 (MEI 2006a). As a result, mechanical intervention is necessary to "redistribute sediment mass" (MEI, 2006a). Restoration techniques recommended for the Middle Rio Grande (Table 3) are taken from Tetra Tech (2004), SWCA (2008) and Baird and Makar (2011). Lessons learned are a collection of observations by individuals as reported by Baird and Makar (2011) and Habitat Restoration Workgroup (HRW 2014) and should be considered valuable but are initial or preliminary findings only. Figure 1 shows the creation of bankline benches technique (see Table 3). Limited post project monitoring indicates restored habitats provide beneficial silvery minnow floodplain habitat (Magana, 2012; SWCA 2014). Large wood can provide important low flow habitat because of the low velocity downstream habitat. Terrace, bank, and island lowering has been shown to provide good silvery minnow habitat for various life stages especially when there are surfaces created that are inundated at different discharges. Bank line embayments, and the entrance to side channels appear to be the techniques that require the most frequent maintenance (about every 1-2 years) (Table 3).

Bank lowered areas also provide good habitat and generally vegetation growth occurs during the first year. This increases the rate of subsequent sediment deposition and may need maintenance every 2-4 years depending on the magnitude and duration of peak flows (Table 3). A more complete description of maintenance of river restoration sites is given in Baird (2016).

Site and Restoration Technique Selection

Site selection can be individual sites that meet specific management objectives or a longer reach approach such that nearby sites are compatible and the interaction between sites is considered. A longer reach approach comprising multiple sites is recommended for maximum habitat benefits and to consider upstream and downstream effects and effects on multiple sites. Site and restoration technique selection are influenced by channel morphology and sediment transport at a reach scale.

Table 3. Restoration Techniques Recommended for the Middle Rio Grande (Tetra Tech 2004; and Baird and Makar 2011)

Technique	Description	Benefits of Technique	Lessons Learned
Passive restoration	Flow regulation could be used to provide higher-magnitude peak flows to accelerate channel processes when water is available. Use of alternative means of channel maintenance to allow where possible opportunities for the river to regain a more natural condition.	Can lead to increased sinuosity (continuation of current bank erosion) and allows opportunity for the development of bars, islands, side channels, sloughs, and braided channels for the development of complex and diverse habitat.	Highly dependent on post-project hydrology.
Large Wood	Placement of trees, root wads, stumps or branches	Creates slow-water habitats for all life stages, provide refugia habitat backwater nutrients, and food sources such as algae.	Can cause downstream sediment deposition filling the slow-water habitat. Life span and sustainability is unknown. Rootwads buried along the ephemeral (Los Lunas) channel provided high flow side channel habitat.
Removal of lateral confinements	Elimination of structural features that reduce bank erosion potential such as jetty jacks.	Creates wider channel and floodplain with more diverse and low velocity habitat	Removal can result in widening of the river and a more dynamic channel. Amount of bankline erosion is dependent upon flow duration, flow patterns and adjacent vegetation and root density. Best if combined with another technique, such as vegetation clearing and bank destabilization.
Creation of bank-line backwaters and embayment	Areas excavated into the banks, bars and high flow side channels to create slackwater habitat, where water from the main channel provides inundation during mid- range and peak flow events.	Retain drifting silvery minnow eggs and juveniles. Provide more complex channel edge habitat. Provide larvae and juvenile development habitat and enhance food supplies	Has provided habitat. Lower entrance elevations provide more habitat value but also more opportunity for sediment deposition. Generally, embayments have a short life span (1-2 years) depending on hydrology. Backwaters often tend to be effective for long periods than embayments.
Island and bar clearing and destabilization	Removal of vegetation by root plowing or raking, disking, and mowing to mobilize the feature during high flows	Creates more complex habitat, channel widening, increased opportunity for backwaters, pools and eddies of variable low velocity and low depth habitat.	Highly dependent on post-project hydrology to mobilize destabilized feature. Difficult to remove established root structure to the extent needed to create instability and erosion of island or bar. Riparian vegetation can regrow unless sediment mobilization can be sustained by river flows.
High-flow side (ephemeral) channels	Channels or areas excavated on islands or bank attached bars such that they carry flow during high river discharge events. Can be constructed for a variety of mid- to high-range flows.	Connect flood plain and the main channel, low velocity and depth habitat for egg and larval development during high flow periods.	Downstream portion can function as a backwater even when ephemeral channel entrance fills with sediment. Maintenance of the channel mouths are likely to be an important element to keep the channel functioning. Using woody debris, log jam, or small riprap structures placed downstream of the inlet can create a zone of flow acceleration to reduce inlet sediment deposition. Inclusion of embayment's can enhance side channel habitat

Technique	Description	Benefits of Technique	Lessons Learned
			benefit. Terraced banks can enhance habitat benefits and diversity.
Creation of bankline benches	Removal of vegetation and excavation of soils along the main channel bankline to create benches that are inundated at a range of medium to large discharges.	Provides shallow water habitat at a range of discharges for spawning, and increased egg/larvae retention.	Inundated bankline benches provided good silvery minnow habitat including spawning, egg retention, and nursery habitat for a variety of flows. Emergent vegetation helped create low velocities. Lower benches experienced some deposition at lower inundation levels. Appear to be able to function for various runoff years. Life- span depends on hydrology and sediment deposition.
Island/Bar modification and lowering	Removal of vegetation and excavation from islands or bars. Create shelves or benches on islands or bars to increase inundation frequency for a large range of discharges.	Provide increased spawning areas, and improved egg/larvae retention. Enhance floodplain connectivity.	Inundated island and bank-attached bars provided good silvery minnow habitat including spawning, egg retention, and nursery habitat for a variety of flows. Emergent vegetation helped create low velocities. Terraced bars and islands experienced some deposition at lower inundation levels. Islands appear to be able to function for various runoff years. Life- span depends on hydrology and sediment deposition. Terracing provides habitat at variable flow rates enhancing silvery minnow use.
Main channel widening	Excavation of banks and lateral expansion of active channel	Intended to reduce average flow velocity, reduce sediment transport capacity and increase lower velocity and shallow depth habitat.	No information on lessons learned is available.

Geomorphic, Hydraulic, and Sediment Analysis

For some reaches geomorphic, hydraulic and sediment analysis may be needed prior to selecting sites, restoration technique, design and implementation. A description of geomorphologic analysis is beyond the scope of this report. For more information on geomorphic principles and assessments, readers are referred to existing publications such as Schumm (2005) and Kondolf and Piegay (2003) among many others. A description of local bar evaluation is included in the next section. Hydraulic analysis may involve either a one-dimensional or two-dimensional hydrodynamic model to characterize inundation surfaces, velocities, depths, and flow patterns.

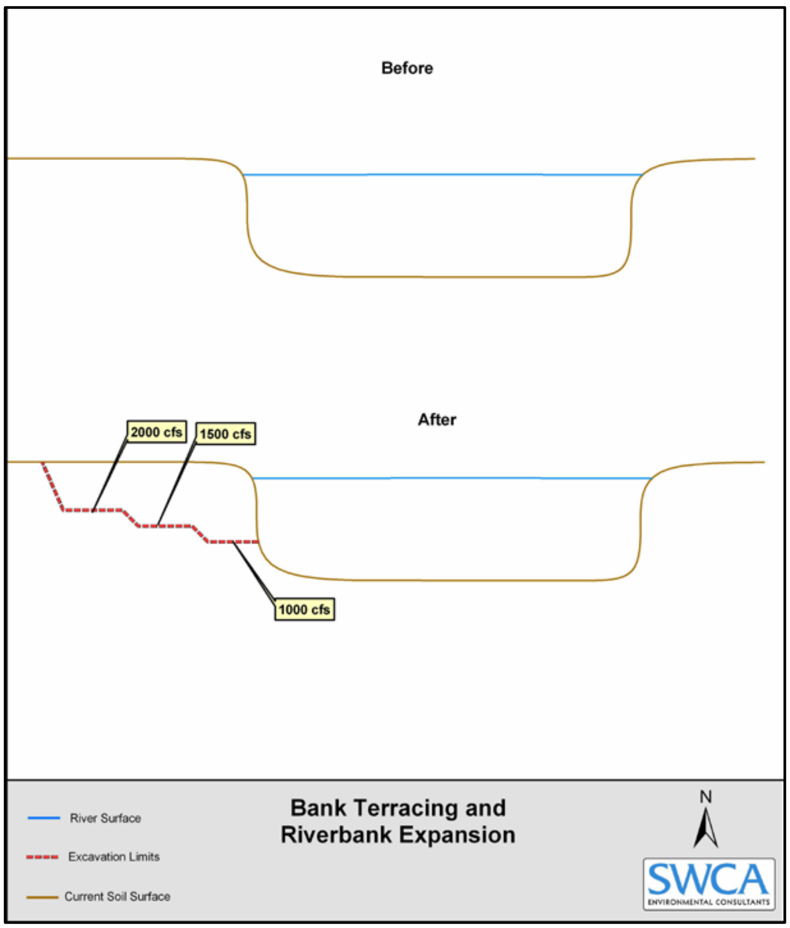

Figure 1. Bank Bench (SWCA 2008) showing surfaces for excavation to the water surface elevation of 1,000, 1,500, and 2,500 cfs river flows. See Table 7 below for a description of creating bankline benches habitat restoration technique.

Site Selection

Site selection for habitat restoration to provide floodplain connectivity is dependent upon the relative site elevation and current frequency and duration of inundation, site availability, and the presence or absence of infrastructure related constraints. Initial screening for site selection is based on identifying and classifying river islands and bank attached bars to distinguish those bars currently providing functioning habitat, and those having conditions most conducive for connectivity.

Mid-channel and bank attached bars provide restoration opportunities based on how frequently they are inundated. MEI (2006a) classified bars on the Middle Rio Grande according to the following characteristics (Ashley 1990; Germanoski 1989):

- Mid-channel or bank-attached
- Vegetated or un-vegetated
- Subaerial or sub-aqueous
- Stationary or mobile
- Fine-grained (sand and finer) or coarse-grained (gravel or coarser).

Based on these characteristics, time sequential aerial photography, and field observations, a hierarchical bar classification was developed (Table 4) (MEI 2006a).

Table 4. Hierarchical Bar Classification for the Middle Rio Grande

Bar Type	Location	Elevation	Subaqueous or Subaerial	Perennial Vegetation
Linguoid*	Mid-channel	Bed	Subaqueous	No
Braid	Mid-channel	Level-1,**	Subaerial	No
Alternate	Bank-attached	Level-1,	Subaerial	No
Mid-Channel	Mid-channel	Level-1,2***	Subaerial	Yes
Bank-Attached	Bank-attached	Level-1,2	Subaerial	Yes

*Submerged, migrating tongue-shaped bars
**Level 1 is above the bed level and emergent during low flows.
***Level 2 bars experience sediment deposition and vertically accrete. Level-1 bars have emergent vegetation and Level-2 have high hydraulic roughness created by perennial vegetation.

Bars that are devoid of vegetation such as linguoid, and braid mid-channel, and alternate bank-attached bars (Table 3) provide current silvery minnow habitat and do not need restoration. Bars with perennial vegetation about a few years old are generally lower elevation than bars with more mature perennial vegetation that have likely experienced vertical accretion due to sediment deposition. Bars with older vegetation would likely require more sediment removal to provide floodplain connectivity than younger vegetated bars. Typically, mid-channel and bank attached Level 2 bars are "inundated about every 3 to 5 years and for durations of less than 5 days per year in the post-Cochiti Dam period. Level 2 bars therefore are primary candidates for restoration" (MEI 2006b). Initial site selection can be accomplished by field mapping of mid-channel and bank attached bar vegetation. Initial screening and site classification may also be based on management decisions that restoration is needed in a particular reach.

In summary, site selection involves these steps (slightly modified from MEI (2006b)):

- Review potential sites
- Classify potential bars
- Determine site availability
- Review infrastructure constraints
- Develop design criteria
- Hydrologic Analysis
  - Inundation duration-(13 (FWS, 2013) to 25 day (MEI, 2006a) or more
  - Determine exceedance flows for inundation targets
    - Dry, wet and normal flow ranges (Section 3.1)
- Site Selection and design discharge (dry, wet and normal flow ranges)
- Convert design/site selection discharge to water surface elevations and determine sites that are inundated for various flows using a hydraulic model (HEC-RAS, SRH-2D).
- For reach scale site selection, the results of the hydraulic model can be used to determine flood plain connectivity acreages for the desired discharge and associated inundation duration.

Restoration Technique Selection

After site selection, restoration technique identification should be accomplished. While there is not a definitive methodology to determine the most applicable restoration technique, selection should consider several factors such as: 1) types and size of sites available, 2) cost, 3) reach or sub-reach based biological needs, and 4) anticipated habitat value. Preliminary results and lessons learned (Table 4) indicate that nearly all restoration techniques improve habitat and are viable. Larger sites provide opportunity for multiple techniques that provide a range of habitat types for spawning, egg/larvae retention, and larval and juvenile development. Larger sites could include terrace, bank and island lowering, ephemeral high flow side channel with embayments and large wood along the high flow side channel. In general, and based on preliminary evaluation (Baird and Makar 2011; HRW 2014) it appears habitat value is relatively high for terrace, bank, and island lowering when restored surfaces are at multiple elevations for inundation over a range of flows. Constructing sloping surfaces that drain to the river could also provide suitable habitat and may help to avoid and minimize stranding of silvery minnow when flows recede depending on the presence and location of sediment deposition. Placement of large wood and embayments enhances side channel habitat value. For a description of long reach selection criteria, see SWCA (2008).

Design Analysis

It is assumed in this section, that geomorphic and sediment analysis, hydrology and hydraulic analysis needed for site selection and technique selection have already taken place. There are specific types of analysis for designing each restoration technique. At the design analysis stage, the hydrology used for site selection will remain the same. The same HEC-RAS, or SRH-2D model should be applied with some adjustment if needed to use final design flows and topography. Many elevations for lowered surfaces have been designed to coincide to the elevation of a selected discharge rather than a velocity or depth. This approach reduces effort for model application. Should velocity and depth be of greater interest for a particular design then a 2-dimensional depth averaged hydraulic model such as SRH-2D could be used. A one-dimensional sediment transport model, or a sediment continuity analysis, would assist in the design by indicating if the reach of interest has tendency for erosion or deposition. At a site-specific scale, a two-dimensional, mobile bed sediment transport model of the restoration design would provide information about the likely or potential channel evolution.

Due to local sediment transport conditions, riverbed elevations changed from measurements used in design, resulting in side channels and floodplain connectivity surfaces being inundated at different flows than planned during project design. In addition, the fixed bed assumption of most hydraulic models creates uncertainty. To account for these uncertainties a factor of safety of additional inundation flow depth or reducing the design discharge can be used. For example, bankline bench elevations corresponding to the water surface elevation for 250, 1,000, 1,500, and 2,500 cfs accounts for hydrologic variability. Using a range of discharge values ensures that some of the restored habitat will be usable for dry, normal or wet years. Lowering surface elevations 0.5 or 1.0 ft. below the design water surface elevation is also a means to provide safety factor to account for bed elevation changes.

In summary, to create the opportunity for reproduction and larval and juvenile development, the risks associated with survey errors, hydrologic variability, and the fixed bed hydraulic calculation assumption are accounted for by:

- Reducing the design flow rate used to determine the elevation of excavation, or
- Reducing the design surface elevation and
- Using variable (three different elevations corresponding to 3 different spring runoff flows) surface elevations.

Post Project Silvery Minnow Use and Channel Response

Limited results of measured habitat usage indicate that the silvery minnow use lateral exchange floodplain habitats (e.g.., Magana 2012; SWCA 2014). Large wood can provide important low flow and over wintering habitat because of the low downstream velocity. Jetty removal can result in bank erosion in areas devoid of trees, or where tree roots have low density. Terrace, bank, and island lowering has been shown to provide floodplain silvery minnow habitat (Magaña 2012; SWCA 2014). While bank line embayments and side channels provide egg retention (Massong et al. 2005), these techniques experience more rapid sediment deposition than other features in Table 3. Maintenance as frequent as every 1-2 years may be needed for these habitat restoration features to remain available for inundation during spring runoff peaks.

Bank lowered areas also provide good habitat and generally vegetation growth occurs during the first year increasing the rate of subsequent sediment deposition and may need maintenance every 2-4 years depending on the magnitude and duration of peak flows. Currently monitoring studies do exist that document silvery minnow occupation at habitat restoration sites (e.g., Magaña 2012; SWCA 2014). However, these reports do not provide monitoring and evaluation of geomorphic channel response. Thus, these limited monitoring evaluations do not provide a broad evaluation of the effectiveness of habitat restoration on the Middle Rio Grande. Furthermore, observations of effectiveness and lessons learned in Table 3 are a collection of individual observations reported by Baird and Makar (2011) and HRW (2014) and can only be considered initial or preliminary findings. These initial observations indicate that most restored sites experience sediment deposition and vegetation re-growth after the first few years depending on the level of inundation (HRW 2014). Additional biological and geomorphic monitoring is needed to understand channel response and silvery minnow use to improve future habitat restoration project value.

Description of effectiveness monitoring and evaluation is outside the scope of this report. Publications by SWCA (2014) provide a summary of habitat restoration effectiveness monitoring steps. Effectiveness monitoring for geomorphic channel response should include repeated light detection and ranging (LiDAR), transects and other surveys of the main channel and habitat restoration site to document sediment deposition or erosion in relationship to flow conditions. Pre-project, as built, and several years of annual post project surveys are recommended. Side channel, backwater and embayment sediment deposition should be documented along with local vegetation. Aerial photography may also be used to provide data for determining geomorphic response.

Summary and Recommendations

Silvery minnows produce numerous semi-buoyant non-adhesive eggs mostly during spring runoff peaks during May or June. Spring runoff peaks that inundate floodplain overbanks are strongly correlated with higher silvery minnow densities measured during fall population monitoring. Silvery minnow spawning and egg drift indicate that lateral floodplain connectivity is a primary need for population recruitment. The species is most often found in low velocity and low depth habitat with silty and sandy substrate with nearby available food sources. Depending on the life stage, highest quality depth habitat is 1.5 ft. or less with mean velocities ranging from 1.5 down to near 0 ft./s. Low velocity areas of sand and silt substrate in proximity of bank lines or emergent vegetation provide food sources.

Habitat restoration projects should focus on increasing overbanking flows through lateral connectivity as well as simulating those features within the main channel where possible (e.g. islands). Systematic monitoring is needed to determine sediment deposition rates in addition to the vegetation and silvery minnow presence or absence monitoring. Geomorphic monitoring including repeat LiDAR, cross section surveys, field descriptions of sediment deposition patterns photographs, and analysis. Geomorphic monitoring should be correlated to habitat monitoring by teaming together biologists, ecologists, geomorphologists and hydraulic engineers. Opportunities to improve habitat restoration longevity, minimize future maintenance needs, determine optimum maintenance timing, and determine tradeoffs between maintaining current habitat restoration sites and developing new habitat restoration sites can be accomplished by evaluating geomorphic response.

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