Population Monitoring Work Group Meeting

November 6, 2019

Meeting Materials:

Agenda

Minutes

Overview of Flow, Habitat, and RGSM Abundance [presentation]

Summary Overview of Flow, Habitat, and RGSM Abundance [presentation]

Steps Towards an Integrated Population Modelling of RGSM [presentation]

RGSM Model Survey [read-ahead]

RGSM Sampling Methods: Population Monitoring (PM) and Population Estimation (PE) [presentation]

Middle Rio Grande Endangered Species Collaborative Program

Est. 2000

Population Monitoring Work Group (PMWG)

Wednesday, November 6, 2019 9:00 AM – 4:00 PM
U.S. Fish and Wildlife Service
2105 Osuna Rd NE, Albuquerque, NM

Call-In Information:
712-451-0011; Passcode 141544#

Meeting Agenda

9:00 – 9:10	**Welcome, Introductions, and Agenda Review** ➢ **Decision**: Approval of November PMWG meeting agenda	*Rich Valdez and Joel Lusk, Work Group Co-Chairs*
9:10 – 9:20	**Review of September PMWG Meeting Minutes** • Action Items review ➢ **Decision**: Approval of September PMWG meeting minutes	*PMWG Co-Chairs*
9:20 – 10:10	**Presentation: RGSM Population Monitoring & Population Estimation Studies** • Discussion	*Rob Dudley, ASIR*
10:10 – 10:40	**Stakeholder Needs for Model** • Questionnaire and member feedback	*Rich Valdez*
10:40 – 10:55	**Break**	
10:55 – 12:20	**Rio Grande Silvery Minnow Model** • Review of model approach and structure • Current progress on the model	*Charles Yackulic*
12:20 – 1:40	**Lunch** *(on own)*	
1:40 – 3:00	**Group Discussion of Model** • Data collection needs to address hypotheses and management questions	*PMWG Co-Chairs*
3:00 – 3:15	**Break**	

3:15 – 3:45	**Overview of Flow, Habitat, and RGSM Abundance**	*Rich Valdez*
3:45 – 4:00	**Work Group Name**	*PMWG Co-Chairs*

- **Decision**: Keep or change the work group name

4:00	**Next Steps and Adjourn**

Middle Rio Grande Endangered Species Collaborative Program

Est. 2000

Population Monitoring Work Group (PMWG)
Meeting Minutes

November 6, 2019 9:00am-4:00pm
Location: U.S. Fish and Wildlife Services
2105 Osuna Rd NE, Albuquerque, NM

Decisions:

- The November 6th meeting agenda was approved.
- The September 4th meeting minutes were approved.

Action Items:

WHO	ACTION ITEM	BY WHEN
Program Support Team (PST)	The PST will email all presentations given at the November 11th meeting to the PMWG members.	ASAP
PST	The PST will share all documents referenced in Rich Valdez's (SWCA) presentation with the PMWG members.	ASAP
PST	The PST will share the habitat data summary produced by Santa Ana Pueblo with the PMWG members.	ASAP
PST	The PST will share the responses to the survey received thus far with the PMWG members.	ASAP
All	The PST and the PWMG signatories will continue to solicit responses to the survey.	January 2020

Next Meeting: TBD

Meeting Notes

Welcome, Introductions, and Agenda Review

Rich Valdez, SWCA and the PMWG Co-chair, and Debbie Lee, PST, opened the meeting and reviewed the agenda.

- **Decision:** The November 6, 2019 PMWG meeting agenda was approved.

Review of September PMWG Meeting Minutes

The work group discussed the status of the American Southwest Ichtyological Researchers (ASIR) contract and their ability to engage with the Program. ASIR is now able to engage with the Program, but will reserve their limited time to working in the background on data needs and requests from the Program.

The group briefly discussed the model survey distributed to the Program, including the continued need for participation in the survey.

- **Decision:** The September 4th meeting minutes were approved.
- **Decision:** The model survey would remain available to the Program.

Presentation: Rio Grande Silvery Minnow (RGSM) Population Monitoring & Population Estimation Studies by Rob Dudley, ASIR

The presentation discussed methodology used by ASIR during the Population Monitoring and Population Estimation efforts.

During the presentation, Rob D. responded as follows to questions and comments from the work group:

RGSM Life History and Sampling Sites

- One work group member noted that variability in flow was minimal during October.
- It was asked if ASIR found any evidence of spawning outside of the spring.
  - Rob D. replied that there was not enough information to be certain. They have caught eggs up until mid-June, but rarely see early-stage larvae in July and never in August, so we suspect spawning does not persist far beyond the spring.
- The group discussed dry sites, and replacement sites for when dry sites were encountered.
  - In 2019 ASIR did not encounter any dry sites during the population monitoring, but in 2018, there were about 9, including sites that were observed as dry on more than one occasion.
- Shoreline pools and runs are different from other pools and runs, as it is possible to seine into a feature.
- Sampling is done a bit differently during high flows and low flows. During high flows, ASIR typically samples the inside bend of the river as it is calmer, safer, and more efficient. They generally do not go over waist-deep because of safety concerns and sampling challenges, except occasionally in runs.

Population Estimation Methods

- Sampling was conducted annually in November, with flow varying between years.
- Disturbance of the habitat and fish was minimized during sampling by keeping the technicians on the periphery of the area during the October GPS mapping. Sampling areas were then flagged with bamboo posts or flags at the site, and ASIR's sampling team would move laterally and quickly to the site. They could not be 100% sure of the percentage of the fish that moved outside the sampling area, but they regularly caught large fish (i.e., catfish and carp) which gave them confidence in the efficiency of the method.
- The sampling device was sealed by a lead skirt on the bottom to reduce the amount of fish escape once the PVC equipment hit the water. The PVC pipes were hollow, so they filled with water and rapidly descended.
- ASIR did not notice a difference between the lengths of the RGSM that were caught in the seine versus the closed sampling device. There was no evidence of a whole cohort of fishing missing, or something similar.
- Dip netting was not as productive in catching fish as the other methods, which was assumed to be attributed to the turbidity of the river.
- Fish lengths were not always recorded in the population estimation work. It depended on the terms of the contract for that year.
- Gary White, ASIR, ran all of the statistics, including the Huggins-type model. Fish lengths were not a part of these analyses.

- There was not a uniform p-hat on all samples because p-hat was established early on when there was enough fish but was not calculated for passes with very few fish.
- ASIR documented all the species caught during this effort. The behavior of the RGSM was noted to be quite different than that of other taxa, with the closest being red shiner.
- ASIR is now contracted to document individual fish lengths in the population monitoring work. Fish are separated into age categories based on length. Though it is difficult to distinguish age based on fish lengths because fish size can vary within an age class depending on the year and growing conditions.
- The catch per unit effort (CPUE) averages presented were from the 20 sites, not the averages of 20 times the number of samples in each site.
- One signatory asked if more information could be gleaned from the confidence intervals around CPUE in "bad" years.
    - This was determined to be a difficult question to answer, and one that was beyond the purview of ASIR as they are not a part of the regulatory decision-making process. ASIR suggested that perhaps genetics could provide additional information, but overall, they were unable to provide an answer to the regulatory challenge of interpreting large confidence intervals in "bad" years.
- Overall, the population monitoring and population estimation trends between years are typically consistent with the exception for the low flow years, when it can be difficult to get a good estimate.
- It was noted that in 2011, low flow conditions resulted in a reduction in habitat availability. By comparison, 2008 and 2009 provided better runoff conditions. It was noted as rare to see high flows in October, which generally has the most stable conditions.
- Funding for the population estimation work ran out in 2011, which is why the work only ran for 4 years.

Occupancy Methods

- Occupancy is defined at the scale of 200m, and is determined using the same 20 sites as sampled during population monitoring.
- It was noted that occupancy is sensitive to the number of sites, and if you wished to tighten the variance on the estimates, there would be a need to include more sites.
- ASIR designed the occupancy work to try to determine what the sampling variance might be across days. It was not designed with the intent of determining occupancy.
- It was noted that the occupancy sampling may be most valuable in "bad" years, with little added benefit in "good" years.

Stakeholder Needs for Model

Rich V. reminded the PMWG members that a survey had been developed and distributed to the Program to determine stakeholder needs for the model being developed by Charles Yackulic, USGS. There have been some responses, but he encouraged PMWG members to discuss the survey with their Executive Committee and ask them to complete it.

- **Action Item:** The PMWG co-chairs will start drafting a report that documents the progress made from this model.

Presentation: Steps towards an integrated population modeling of Rio Grande Silvery Minnow

Charles Y. provided an update on the model he has been developing for RGSM, under contract with NM Interstate Stream Commission. During his presentation, Charles responded to questions and comments from the work group members:

Spatial scale:

- When discussing "movement," that refers to movement between ten-mile segments of the river. At that scale, there is at least one monitoring site in each segment.
- The spatial scale picked will affect the predictions of the model. Charles is still determining if the data available will support finer resolution estimates.
- Charles has not looked at how the ten-mile segments correspond with geomorphic features.
- It is possible to have the model run for a certain area, and not for the whole MRG in order to reduce computation problems. But it is a complex exercise.

Drying data:

- Charles is using the drying data to explore whether some fish were moving before drying events. This would contribute to our understanding of salvage data, and how it would relate to the fish population number in a reach.
  - One member suggested he also look at predation and food availability related to drying events. This may limit recolonization of those areas by fish.
  - Rob D. noted that ASIR has not noticed a rapid recolonization of dry areas.

Data availability and capacity:

- There is a lack of data on estimates of larval survival. There are estimates of egg survival from laboratory studies.
- Whether Charles will be able to incorporate time in the movement analyses will depend on the data capabilities.
- Charles noted a need to understand sampling variability. If you can determine how much of the variability is due to the sampling process, you can adjust and prevent falsely concluding there is density dependence.

Group Discussion of the Model
The PMWG then discussed the model being developed by Charles. He noted that there are a lot of parameters in the model, and in order to be able to perform simpler analyses, he has to determine what the reasonable ranges for the parameters are. He still has to take a harder look at the mark-recapture data. The model will be documented in R code for visibility and transparency.

During the conversation, PMWG members asked questions:

- Question: Will the model inform management decisions given limited water and limited flexibility?
  - Answer: It will be eventually possible. Charles anticipates being able to manipulate the model in the future to answer management questions. He is also looking to add management costs in order to estimate how changes in management (and management costs) result in changes in the population. There may be different versions of the model to accomplish this.
- Question: Will the model take into account only the constraints of the system today, or will it "think outside the box"?
  - Answer: This will depend on what folks want. The management constraints can always change in reality. Ideally, stakeholders would be coming up with management options and alternatives that could influence this. Or, the group may

just want to explore possibilities, even without an expected policy change. Ideally, there would be a tool where people could run alternatives and scenarios themselves and see the outcome.

- Question: Is the model taking into account genetics?
  - Answer: Not at this point.
- Question: Is mark-recapture a feasible way to look at abundance for RGSM?
  - Answer: It would involve really intensively sampling one area during a year when there are a lot of fish. There are trade-offs with PIT tags: while they can offer better data, they have higher mortality than VIE tags. One possibility is to break up a study area into different sections and study movement between using differently colored VIE-tagged fish. You could tailor this study to answer very specific questions (for example, upstream and downstream of a diversion dam).
- Question: What are some options for reducing uncertainty?
  - Answer: First, Charles would want to look at the existing data to see if there is more to be gleaned from it. Then, specifically design studies to fill in gaps in order to reduce uncertainties.
    - BACI (before, after, control, impact) designed studies might help better the impact of restoration work.
    - One possibility is to compare years where there was not a lot of restoration work with years where there were, over similar flows. The Albuquerque area might be a good site for such a study.

Presentation: Overview of Flow, Habitat, and RGSM Abundance
Rich gave a presentation, "Overview of Flow, Habitat, and RGSM Abundance," which included a compilation related studies and their models, parameters, results, and conclusions. The group had an in-depth discussion about mesohabitats and the characteristics of the mesohabitats.

Next Steps:

- Next meeting date: TBD

The PST will coordinate with Charles on potential next meeting dates.

Meeting Participants

Trevor Birt, N.M. Interstate Stream Commission
Dave Campbell, U.S. Fish & Wildlife Service
Rob Dudley, American Southwest Ichthyological Researchers
Lynette Giesen, U.S. Army Corps of Engineers
Grace Haggerty, N.M. Interstate Stream Commission
Mo Hobbs, Albuquerque-Bernalillo County Water Utility Authority
Shay Howlin, Western EcoSystems Technology
Debbie Lee, Western EcoSystems Technology
Anne Marken, Middle Rio Grande Conservancy District
Michael Porter, U.S. Army Corps of Engineers
Kiara Takacs, Western EcoSystems Technology
Ashley Tanner, Western EcoSystems Technology
Clint Smith, U.S. Fish & Wildlife Service
Rich Valdez, SWCA
Ara Winter, Bosque Ecosystem Monitoring Program
Charles Yackulic, U.S. Geological Survey

Preliminary – Subject to Revision

Overview of Flow, Habitat, and RGSM Abundance

Rich Valdez

Population Monitoring Workgroup Meeting

Albuquerque, NM

November 6, 2019

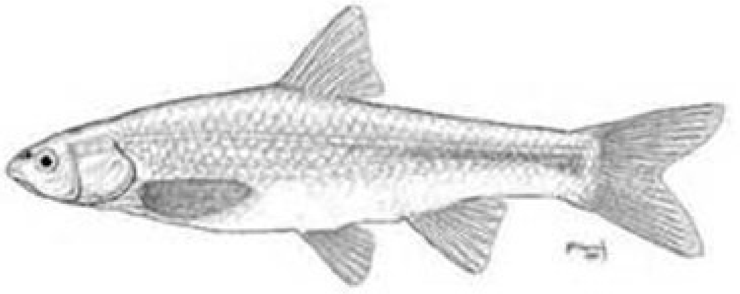
The Issue:

The abundance parameter is vital to an integrated model.

There is a need to quantify total RGSM abundance as related to habitat and flow

- Abundance is defined as total number of individuals in the population (not CPUE)

Purpose for this Overview



- To assimilate and review relevant literature.
- To initiate a conversation of the PMWG.
- To reconcile the relationship of flow, habitat, and RGSM abundance.

Key Documents—Flow, Habitat, and RGSM Abundance

1. Bovee, K.D., T.J. Waddle, and J.M. Spears. 2008. Streamflow and endangered species habitat in the lower Isleta reach of the Middle Rio Grande. US Geological Survey, Open-File Report 2008-1323.

2. Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2011, 2012. Rio Grande silvery minnow population estimation program results from October 2010 (2011). Final Report. American Southwest Ichthyological Researchers, L.L.C., Albuquerque, NM.

3. Miller, P.S. 2012. A RAMAS-Based Population Viability Model for the Rio Grande silvery minnow (*Hybognathus amarus*). Final Report, Middle Rio Grande Endangered Species Act Collaborative Program, Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN.

4. Tetra Tech, Inc. 2014. Ecohydrological relationships along the Middle Rio Grande of New Mexico for the endangered Rio Grande silvery minnow. Final Report, Contract WP912PP-08-D-0009-0-20, Task Order 20, Task 5. U.S. Army Corps of Engineers, Albuquerque District, Albuquerque, NM.

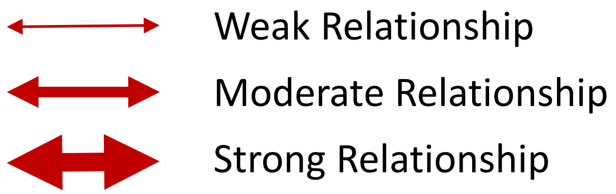
5. Braun, C.L., D.K. Pearson, M.D. Porter, and J.B. Moring. 2015. Physical characteristics and fish assemblage composition at site and mesohabitat scales over a range of streamflows in the Middle Rio Grande, New Mexico, Winter 2011–12, Summer 2012. U.S. Geological Survey, Investigations Report 2015–5025. U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service, Albuquerque, NM.

6. U.S. Fish and Wildlife Service. 2016. Appendix A: Analytical framework for evaluating the proposed water management and maintenance actions on Rio Grande silvery minnow, southwestern willow flycatcher, and yellow-billed cuckoo and their critical habitats. Final Biological and Conference Opinion for Bureau of Reclamation, Bureau of Indian Affairs, and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico, Consultation Number 02ENNM00-2013-F-0033, U.S. Fish and Wildlife Service, Albuquerque, NM.

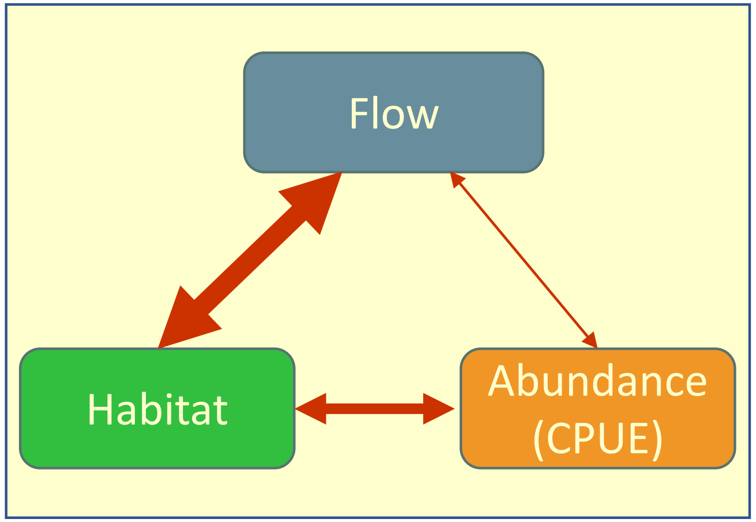
7. Yang, Y., K. LaForge, and P. Julien. 2018. Middle Rio Grande—Isleta Reach: Isleta Diversion Dam to Rio Puerco, hydraulic modeling and silvery minnow habitat analysis, 1918-2016. Draft Report, August 2018, Prepared for: U.S. Bureau of Reclamation, Colorado State University, Engineering Research Center, Department of Civil Engineering, Fort Collins, CO.

8. Budy, P., and T.E. Walsworth. 2019. Review of the "Analytical framework for evaluating the proposed water management and maintenance actions on Rio Grande silvery minnow, southwestern willow flycatcher, and yellow-billed cuckoo and their critical habitats" with recommendations for future analytical considerations. USGS Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, UT.

Summary of Key Documents Principal Variables:

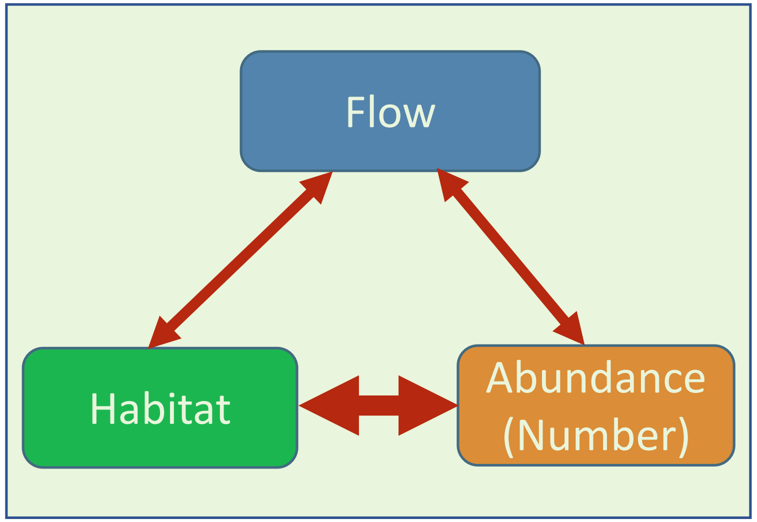


Strong Relationship:
Flow to Habitat



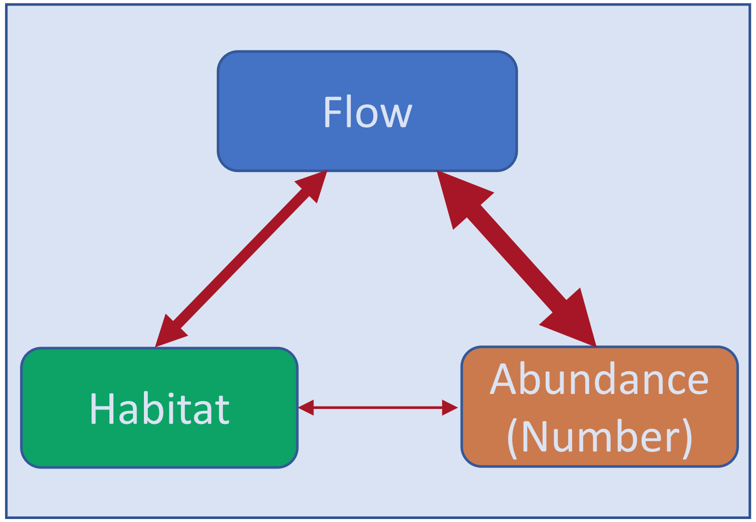
- Bovee et al. (2008)
- Tetra Tech (2014)
- Braun et al. (2015)
- Yang et al. (2018)

Strong Relationship:
Habitat to Abundance



- Dudley et al. (2011, 2012)
- Miller (2012)

Strong Relationship:
Flow to Abundance



- USFWS (2016)
- Budy and Walsworth (2019)

1a – Bovee

Bovee et al. (2008)

- Objectives:
  - Evaluate effects of different operational modes of the Bernardo siphon on habitat for *H. amarus* and *E. t. extimus* in this section of river.
  - Increase operational flexibility and improve irrigation delivery efficiency to the Socorro main canal at San Acacia Dam.
  - The “Bernardo Siphon” has been proposed to intercept up to 150 cfs from the Lower San Juan Riverside Drain on the east side of the Rio Grande and transport it under the river into a drainage canal on the west side.
- Used a two-dimensional hydraulic simulation model (PHABSIM) to simulate hydraulic conditions for a range of discharges at three study sites in the Rio Grande between the proposed siphon location and San Acacia Dam.

1b – Bovee

Figure 2. San Acacia diversion dam and diversion headworks. Photograph by Paul Tashjian accessed from http://www.fws.gov/southwest/bhg/images/san1.htm, November 2007

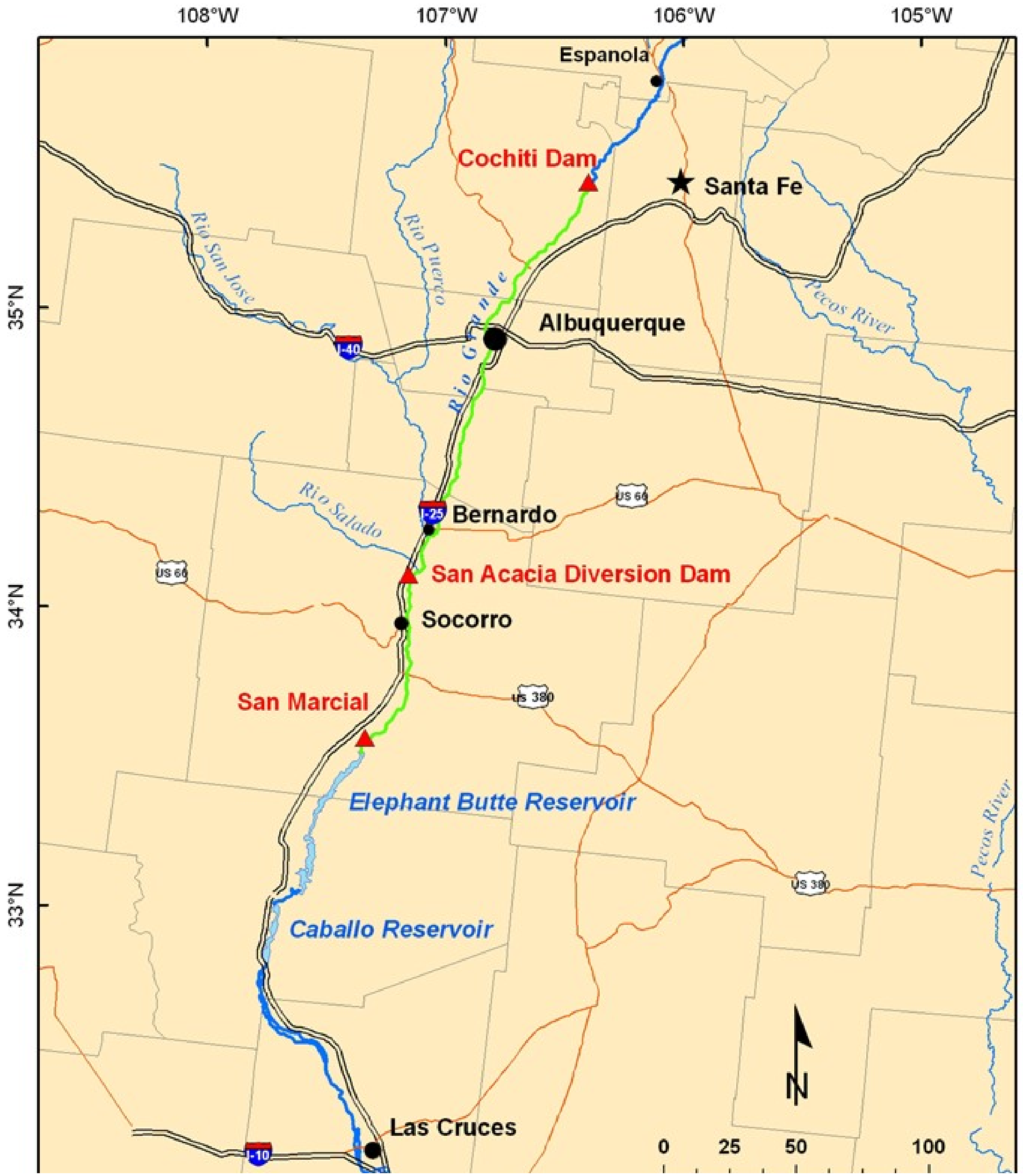


Figure 1. Map showing the New Mexico portion of the Rio Grande, the location of the San Acacia diversion dam, and the approximate extent of the critical habitat designation for *H. amarus* (in green).

1c – Bovee

Suitable habitat characteristics were defined for H. amarus by consensus of a panel of experts (i.e., Delphi).

These criteria were also used by Tetra Tech (2014), Braun et al. (2015), and Yang et al. (2018).

Table 2. Summary of habitat suitability criteria for the Rio Grande silvery minnow, with justification for deviations from criteria in the U. S. Fish and Wildlife Service recovery plan (1999).

	Criteria source		
Criteria type	Technical advisory group June 2007	Recovery plan 1999	Technical advisory group (final) November, 2007
Adult depth range	• 10 cm, no upper limit	• 50 cm, no lower limit given	5 cm [a]–50 cm [b]
Juvenile depth range	• 5 cm, no upper limit	• 50 cm, no lower limit given	5 cm [a]–50 cm [b]
Adult velocity range	0–60 cm/s	0–40 cm/s	1 cm/s [c]–40 cm/s [d]
Juvenile velocity range	0–30 cm/s	0–40 cm/s	1 cm/s [c]–30 cm/s [e]

Justification for modifications:

[a] Minimum depth set at 5 cm for potential habitat use at shallower depths consistent with feeding biology .
[b] Maximum depth changed to 0.5 m for consistency with recovery plan.
[c] Minimum velocity set at 1 cm/s to differentiate flowing water from stagnant pools.
[d] Maximum velocity for adults reduced for consistency with recovery plan.
[e] Maximum velocity for juveniles reduced from recovery plan to reflect sustained swimming performance of post-larval fish.

1d – Bovee

Habitat criteria are used to define suitable areas of the river channel, but are not linked to RGSM abundance.

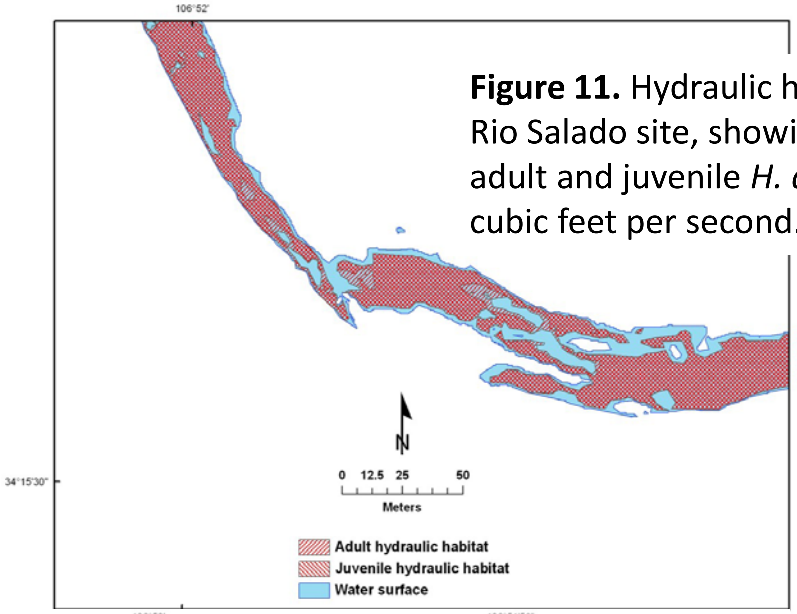


Figure 11. Hydraulic habitat map for a portion of the Rio Salado site, showing suitable conditions for adult and juvenile *H. amarus* at a discharge of 20 cubic feet per second.

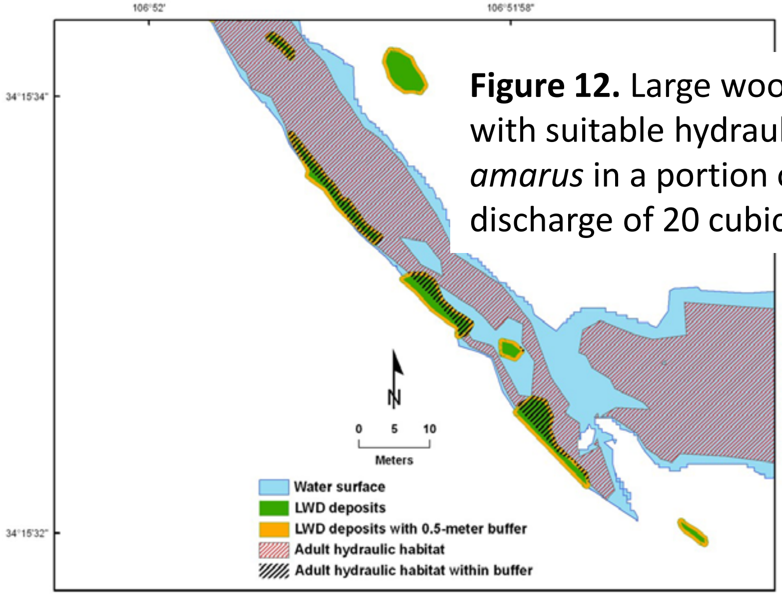


Figure 12. Large woody debris buffers intersected with suitable hydraulic habitat layers for adult *H. amarus* in a portion of the Rio Salado site at a discharge of 20 cubic feet per second.

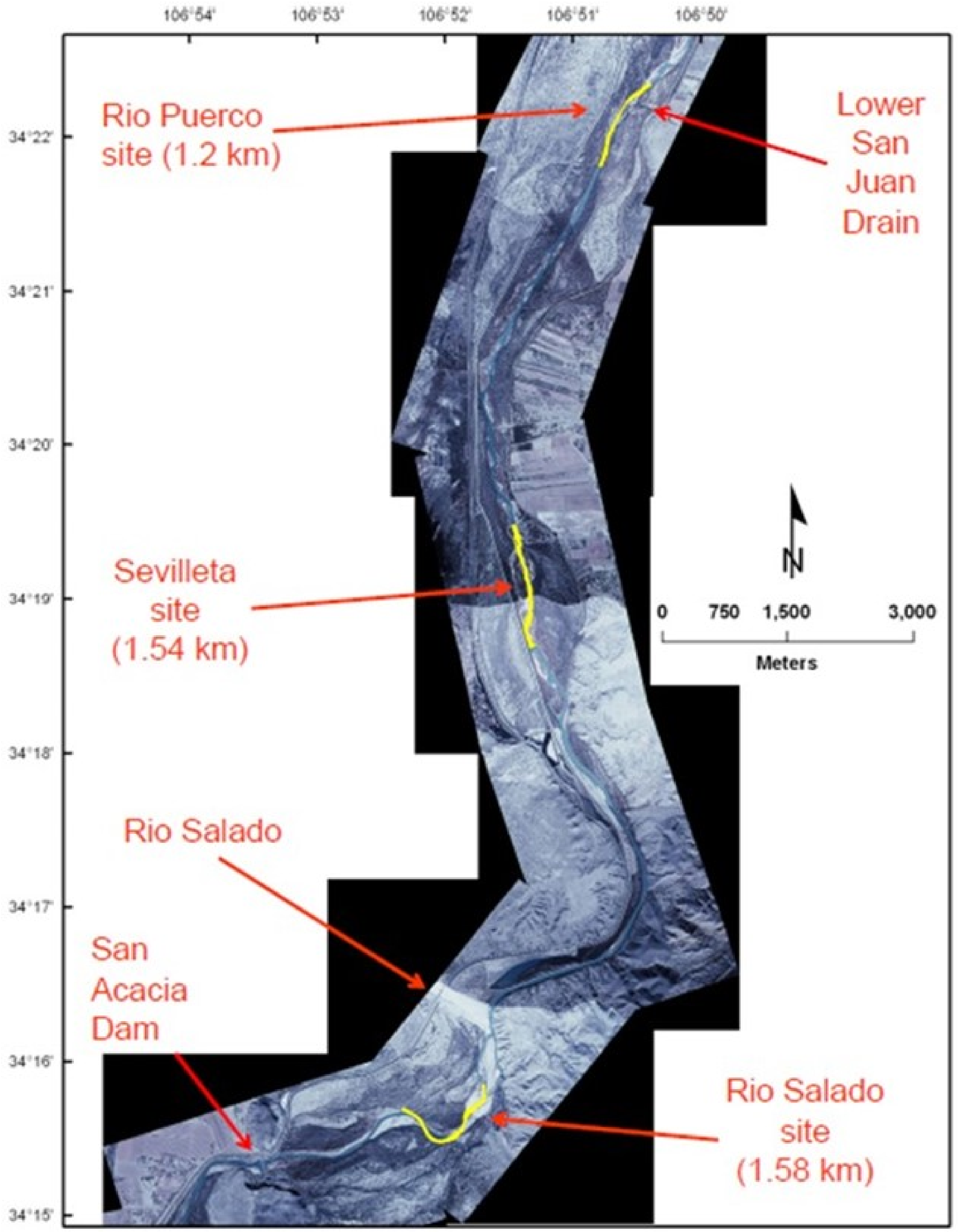


Figure 6. Aerial photograph mosaic of the lower Isleta study area, showing locations of study sites.

1e – Bovee

Habitat criteria are used to define suitable areas of the river channel, but are not linked to RGSM abundance.

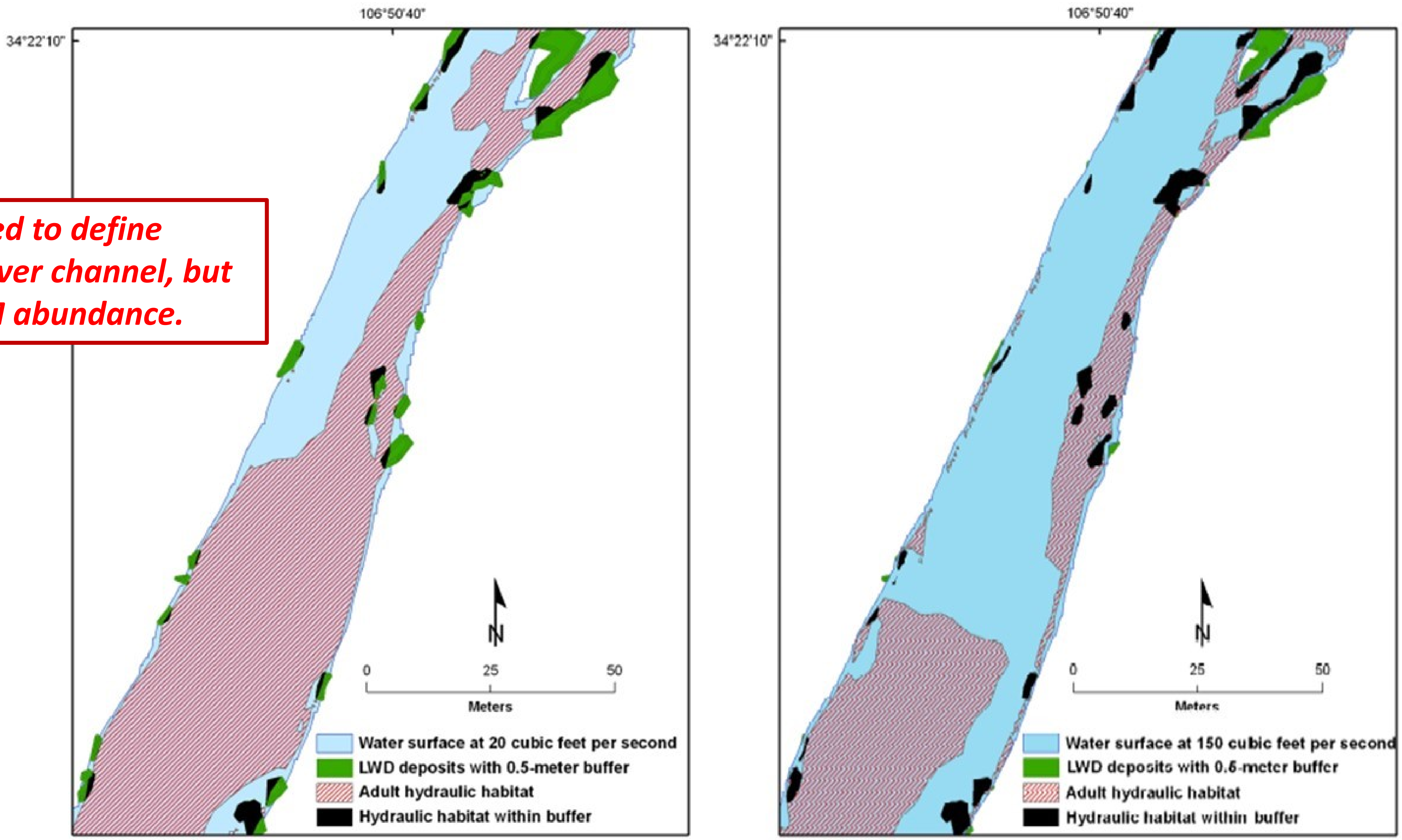
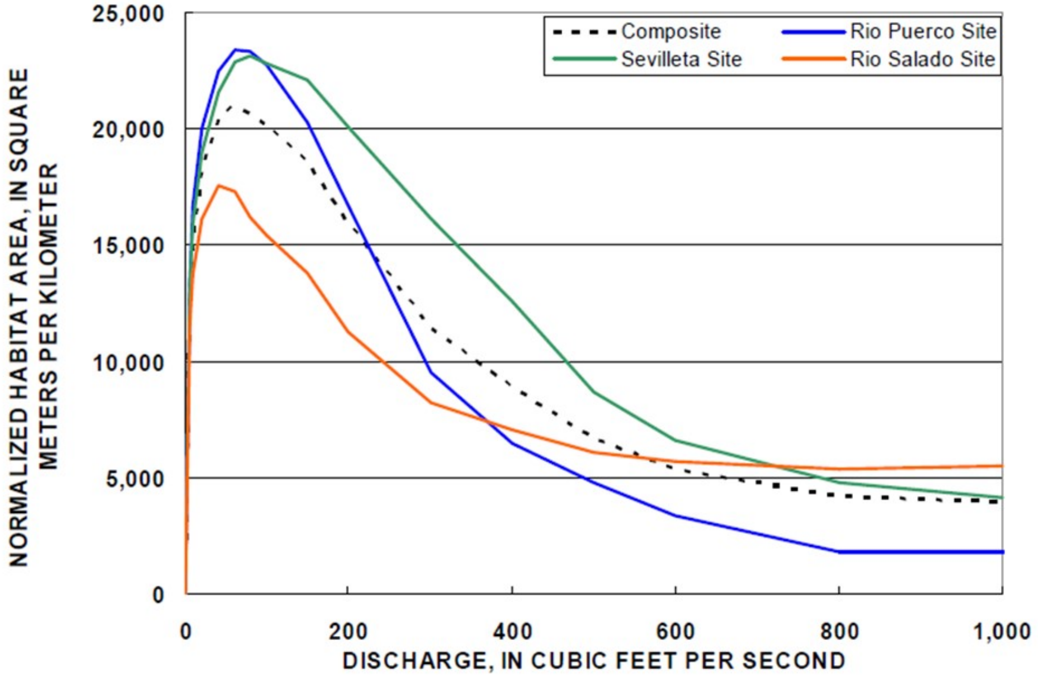


Figure 33. Juxtaposition of large woody debris deposits and suitable hydraulic habitat for adult *H. amarus* in a portion of the Rio Puerco site at 20 cubic feet per second and at 150 cubic feet per second.

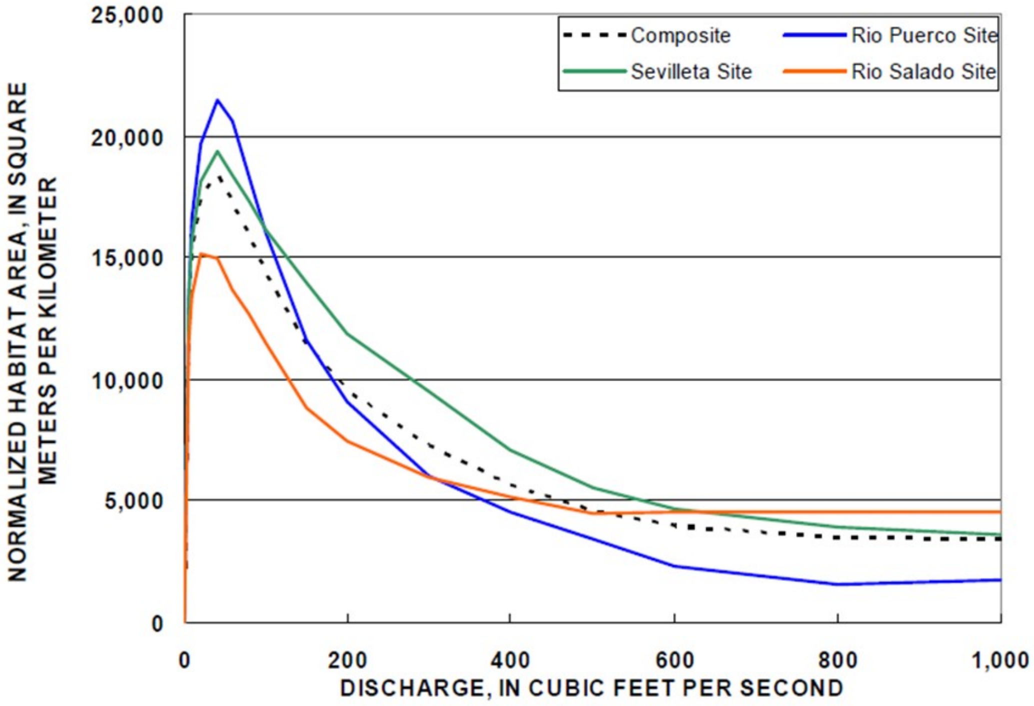
1f – Bovee

Figure 29. Normalized hydraulic habitat area as a function of discharge for adult *H. amarus*.



Habitat criteria are used to define suitable areas of the river channel, but are not linked to RGSM abundance.

Figure 30. Normalized hydraulic habitat area as a function of discharge for juvenile *H. amarus*.



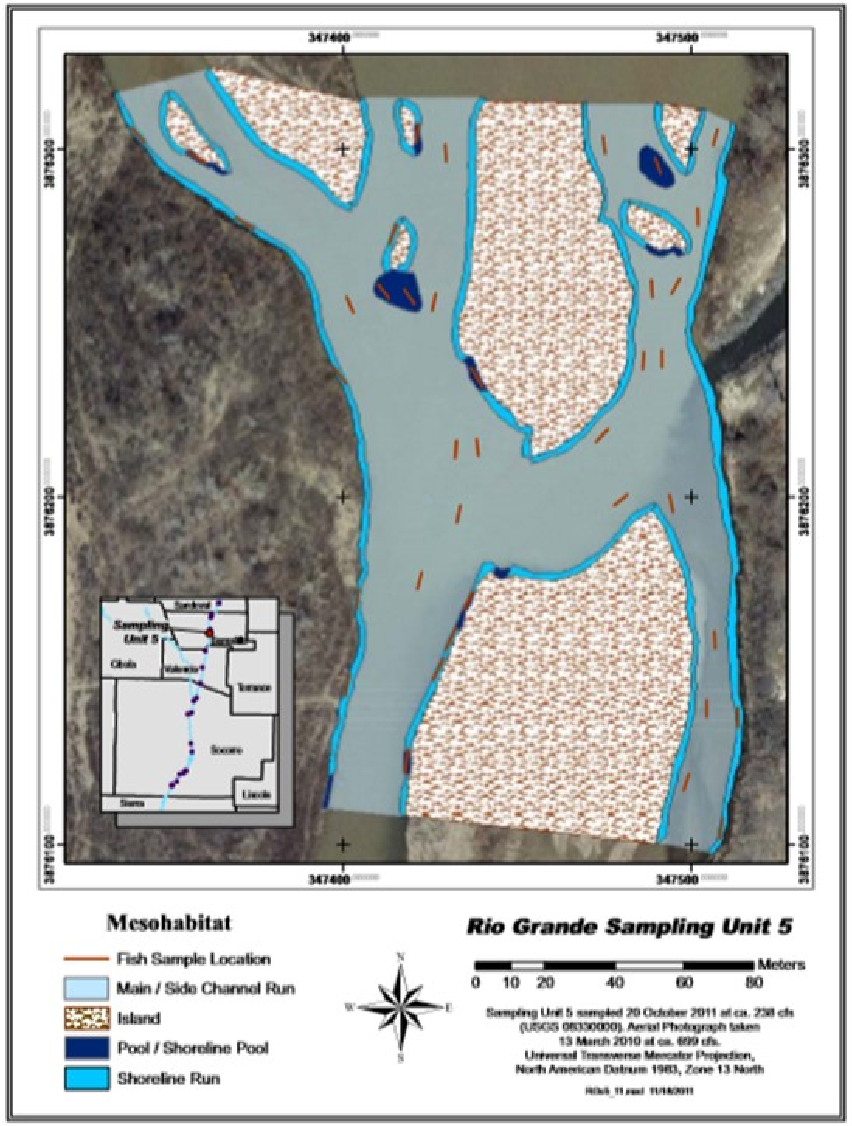
2a – Dudley

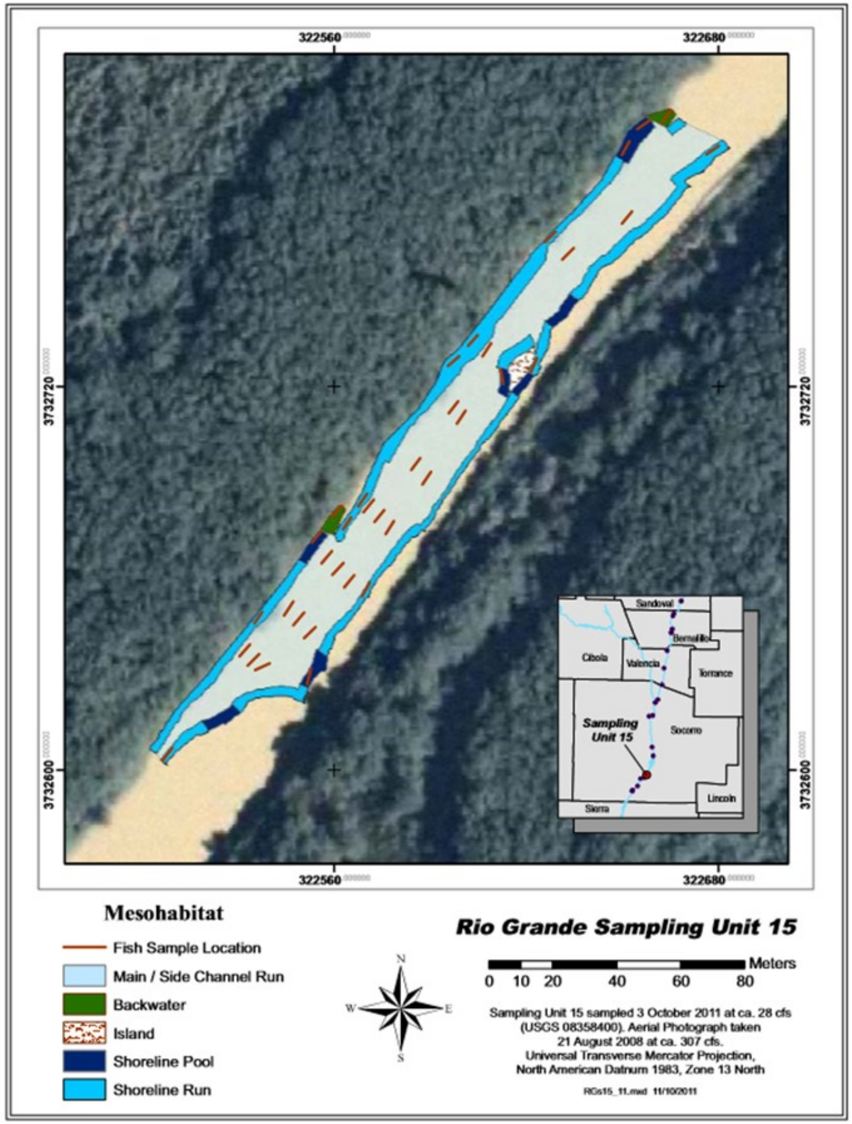
Dudley et al. (2011, 2012)

- Objectives:
  - Estimate numbers of RGSM by reach and total in the MRG.
  - Quantify relationship of RGSM CPUE to total numbers.
- Used multiple depletion estimator by electrofishing within enclosures by mesohabitat.
- Estimates taken in October for 2008, 2009, 2010, and 2011.

2b – Dudley

Mesohabitat area measures and maps delineate habitat types and areas for each sample period at flow.

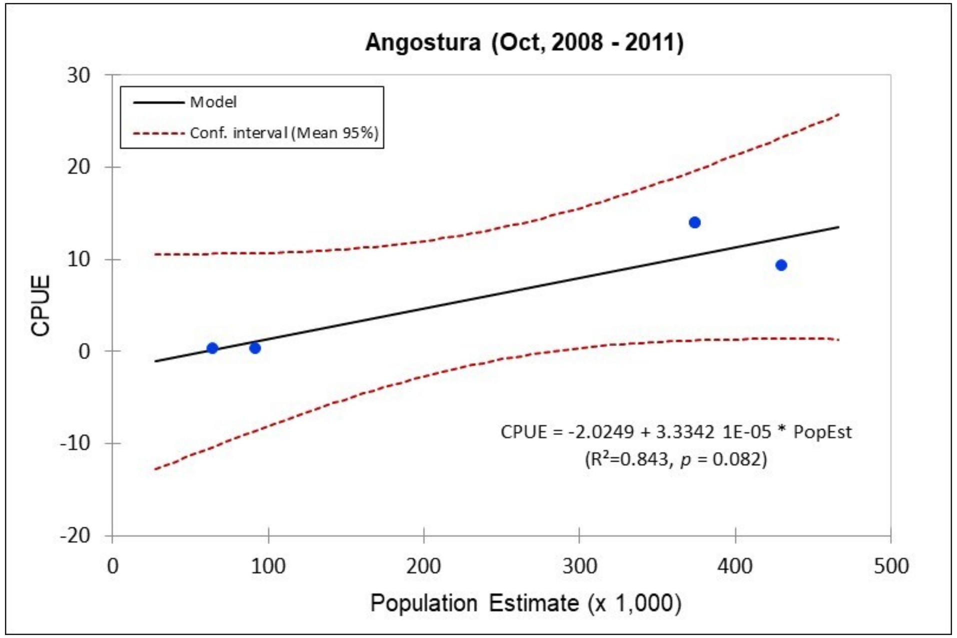


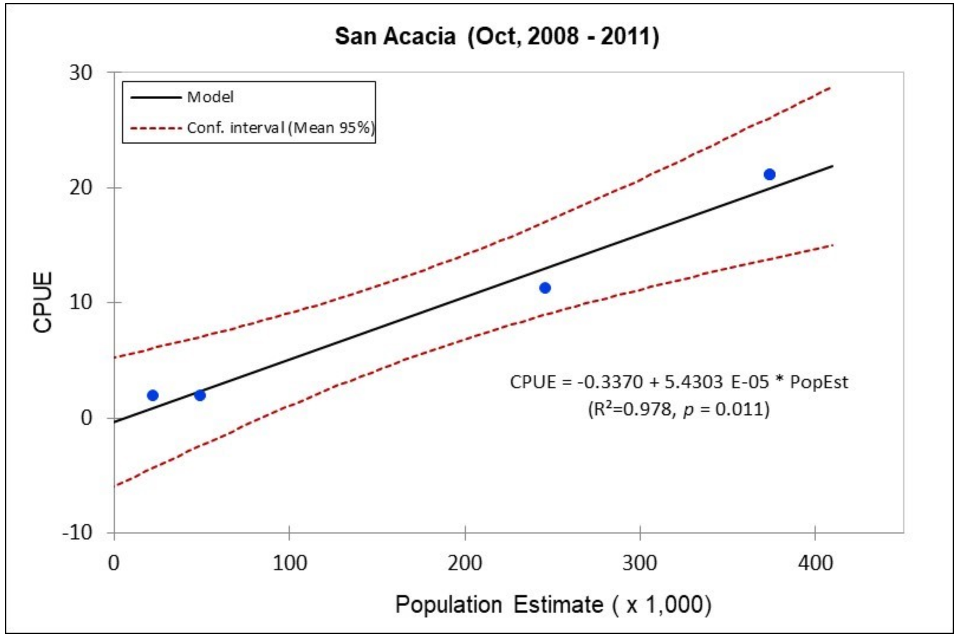


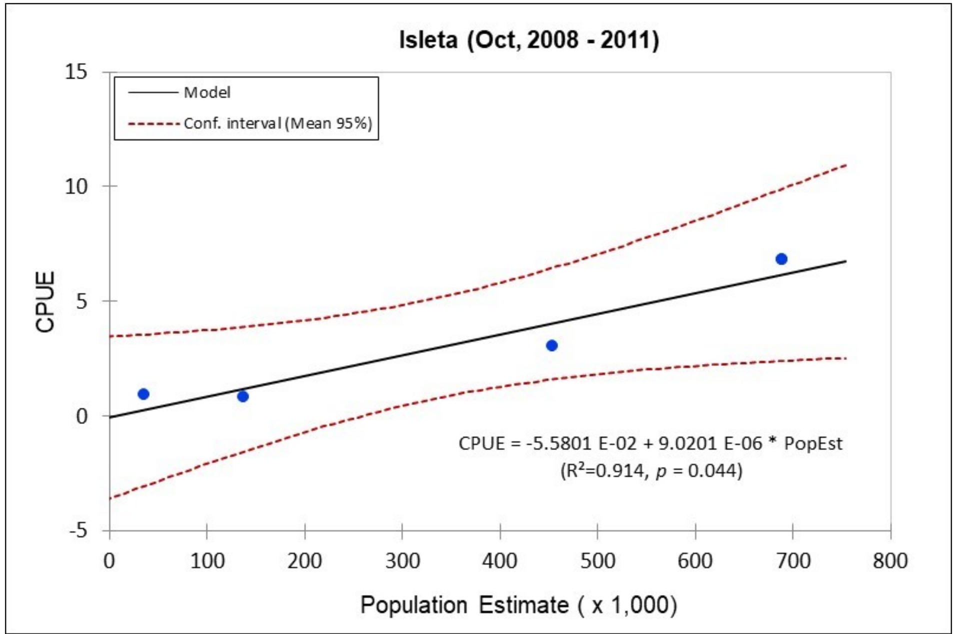
2c – Dudley

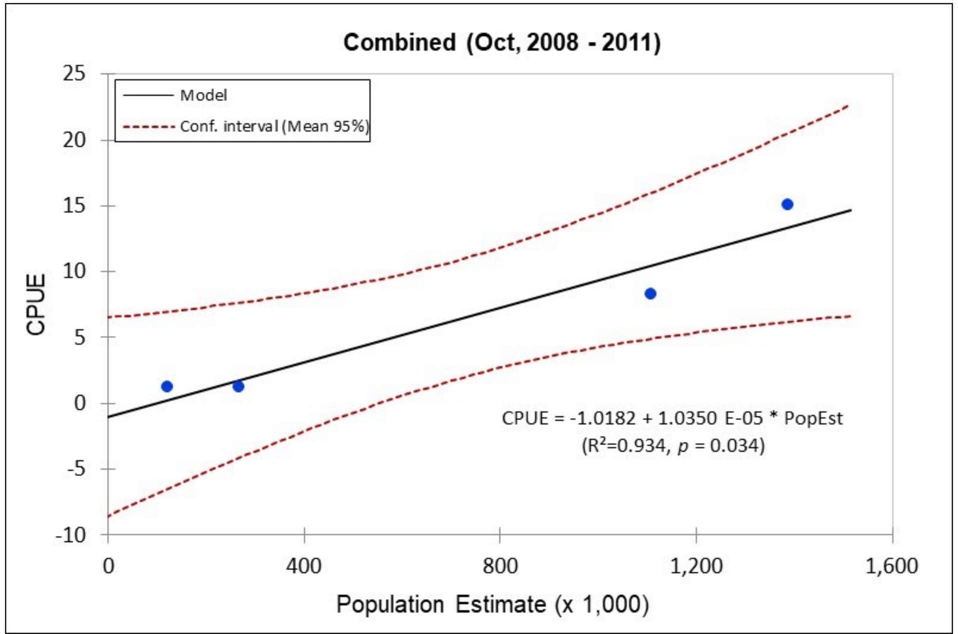
Relationship of CPUE to Pop Est is strong by reach and combined (R^2 = 0.84 – 0.98).

Figures developed by R. Valdez (6/15/2018)









2d – Dudley

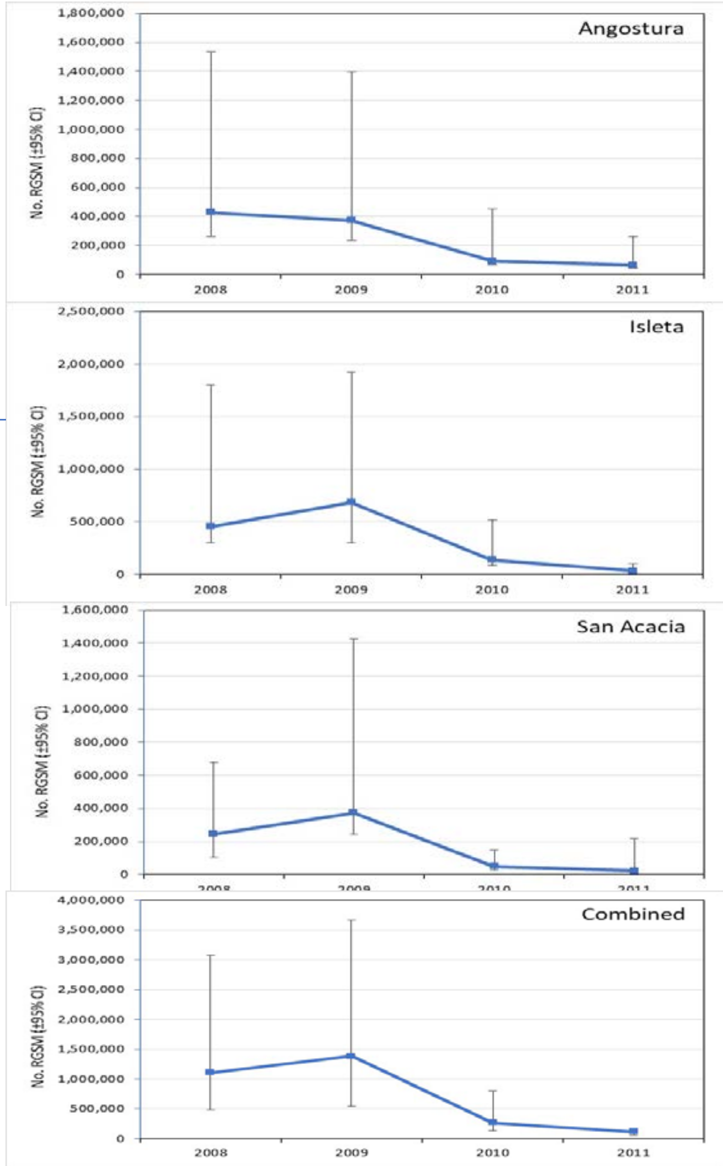
Total numbers of RGSM by reach and for MRG are for October by year.

Estimates of Rio Grande silvery minnow population size (unmarked individuals only)

Project	Year	Reach	Estimate	Lower 95% CI	Upper 95% CI
Population Estimation	2008	Angostura	429,544.58	166,651.59	1,107,151.46
Population Estimation	2009	Angostura	374,515.10	137,452.05	1,020,439.96
Population Estimation	2010	Angostura	92,008.76	23,572.76	359,126.88
Population Estimation	2011	Angostura	64,207.21	20,969.71	196,596.19
Population Estimation	2008	Isleta	453,266.74	152,384.15	1,348,242.14
Population Estimation	2009	Isleta	688,256.83	382,896.79	1,237,141.40
Population Estimation	2010	Isleta	137,486.21	49,521.56	381,701.60
Population Estimation	2011	Isleta	34,891.17	18,356.90	66,318.05
Population Estimation	2008	San Acacia	246,362.30	139,867.89	433,940.80
Population Estimation	2009	San Acacia	374,320.84	133,086.93	1,052,816.28
Population Estimation	2010	San Acacia	49,319.23	24,683.69	98,542.23
Population Estimation	2011	San Acacia	22,505.00	9,894.54	196,596.19
Population Estimation	2008	Combined	1,108,430.23	623,544.06	1,970,378.12
Population Estimation	2009	Combined	1,387,948.14	842,933.46	2,285,352.43
Population Estimation	2010	Combined	267,271.94	132,055.17	540,942.76
Population Estimation	2011	Combined	122,380.55	59,971.52	51,187.33
Population Monitoring	2008	Angostura	58,991.04	24,483.06	142,136.75
Population Monitoring	2009	Angostura	108,183.69	54,203.03	215,923.57
Population Monitoring	2010	Angostura	19,283.00	8,519.12	43,647.00
Population Monitoring	2008	Isleta	209,044.46	105,491.13	414,248.90
Population Monitoring	2009	Isleta	305,975.56	152,900.73	612,299.52
Population Monitoring	2010	Isleta	27,655.50	11,913.05	64,200.76
Population Monitoring	2008	San Acacia	276,512.41	200,984.23	380,423.46
Population Monitoring	2009	San Acacia	224,427.01	117,277.83	429,471.47
Population Monitoring	2010	San Acacia	22,121.46	8,744.15	55,964.20
Population Monitoring	2008	Combined	544,170.27	393,990.38	751,595.22
Population Monitoring	2009	Combined	619,453.30	411,414.74	932,689.95
Population Monitoring	2010	Combined	68,138.92	41,318.39	112,369.17

- electrofishing
- multiple depletion
- by mesohabitat type
- $\hat{p}$ computed
- expanded by area

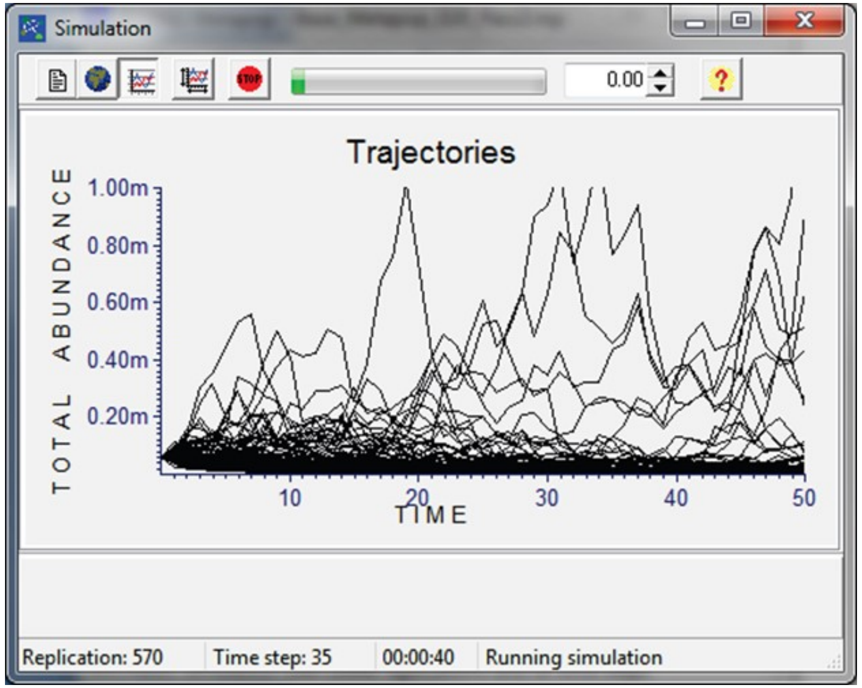
- open seine
- CPUE
- by mesohabitat type
- $\hat{p}$ set to 1.0
- expanded by area

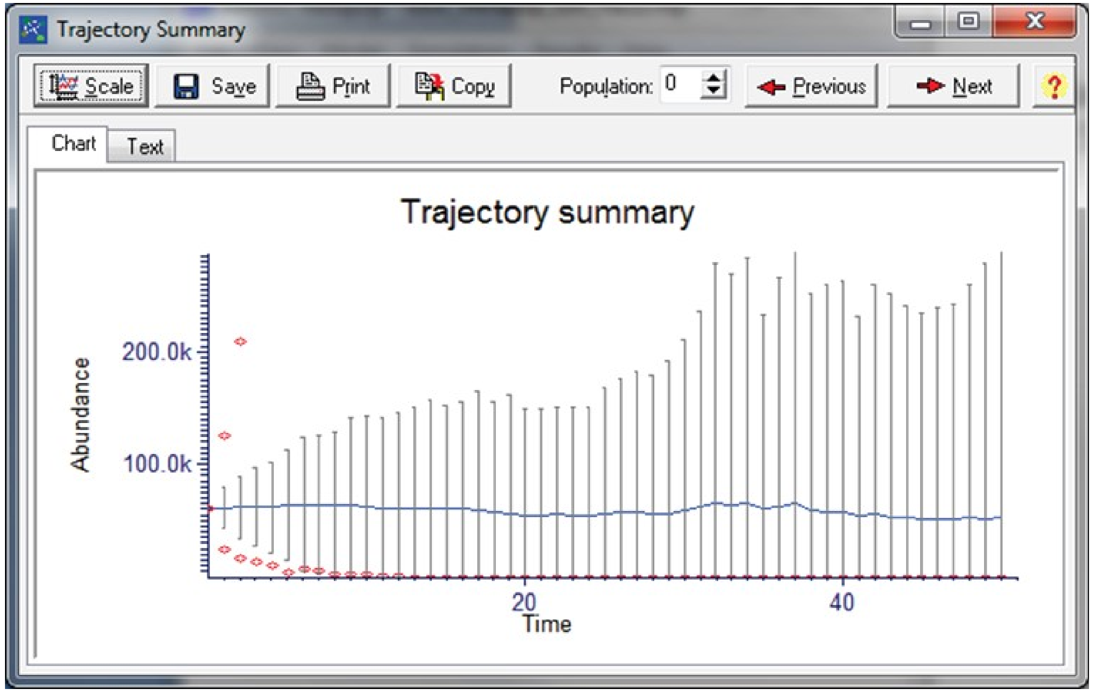


3a – Miller

Miller et al. (2012)

- Develop a Population Viability Analysis (PVA) to evaluate extinction probability of RGSM to various environmental correlates (e.g., flow)





3b – Miller

Page 10 from Miller (2012)

Stock Assessment model is initialized with Total Abundance from Dudley et al. (2012).

Initial population size
In order to construct a meaningful PVA model, we must derive even an estimate of population size so that we can evaluate the impact of predicted growth dynamics that emerge from our Leslie matrix analysis. We must therefore assess the appropriate information available to us and decide on a productive course of action.

Recent population estimation analyses, conducted by ASIR (e.g., Dudley et al. 2012), are valuable sources of initial population size estimates across the Middle Rio Grande. The October 2011 population size estimates for each reach were used as initial abundance values for the models described here. These values are given below.

See next slide from Dudley et al. (2012)

Reach	Total Abundance	Female Abundance
Angostura	64,207	32,104
Isleta	34,891	17,446
San Acacia	22,505	11,253

Initial abundances were apportioned automatically in accordance with that expected from a stable age distribution. Note that these abundance estimates are rather low compared to earlier estimates. This starting point for the models discussed here may be instructive for understanding the impact of small population instability on persistence probabilities.

3c – Miller

Dudley et al. (2012): Table 8. Rio Grande silvery minnow 2011 population estimation results for all sampling reaches and the overall study area in the Middle Rio Grande (all individuals and unmarked individuals only).

Rio Grande silvery minnow (all individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	233.48	326.48	275	64,207.21	39,858.79	20,969.71	196,596.19
Isleta	82.88	68.44	421	34,891.17	11,746.55	18,356.90	66,318.05
San Acacia	47.48	62.80	474	22,505.00	9,865.74	9,894.54	51,187.33
Combined	104.60	177.20	1,170	122,380.55	46,051.61	59,971.52	249,735.18

Rio Grande silvery minnow (unmarked individuals only)

These estimates were used by Miller (2012) to initialized the Stock Assessment Model of PVA).

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	233.48	326.48	275	64,207.21	39,858.79	20,969.71	196,596.19
Isleta	82.88	68.44	421	34,891.17	11,746.55	18,356.90	66,318.05
San Acacia	47.48	62.80	474	22,505.00	9,865.74	9,894.54	51,187.33
Combined	104.60	177.20	1,170	122,380.55	46,051.61	59,971.52	249,735.18

4a – TetraTech

- Objectives—estimate area of:
  - Most Commonly Occupied Habitat,
  - Highest Quality Feeding and Rearing Habitat, and
  - Highest Quality Spawning and Egg/Larval Retention Habitat.
- Methods:
  - Two-dimensional hydrodynamic model (RMA2 and the Surface Water Modeling System or SMS) with capability of predicting depth and velocity values on a finite grid.
  - URGWOPS hydraulic model results coupled with habitat use criteria and hypothetical hydrologic time series derived of usable habitat area for native and non-native fish species at eight study sites (six on the Rio Grande and two on the Rio Chama).
  - Approach parallels flow-habitat relationships of the Instream Flow Incremental Methodology (IFIM; Bovee 1982; Bovee et al. 1998).

4b – TetraTech

Note: Tetra Tech used the same habitat criteria developed in Bovee et al. (2008)—the Delphi consensus process

Table 5. Summary of habitat suitability criteria for the Rio Grande silvery minnow, with justification for deviations from criteria in the 1999 USFWS Recovery Plan (table reproduced from Bovee et al. 2008).

	Criteria source		
Criteria Type	**Technical Advisory Group (Initial) June 2007**	**Recovery Plan 1999**	**Technical Advisory Group (final) November, 2007**
Adult depth range	10 cm, no upper limit	50 cm, no lower limit given	5 cm[a]–50 cm[b]
Juvenile depth range	5 cm, no upper limit	50 cm, no lower limit given	5 cm[a]–50 cm[b]
Adult velocity range	0–60 cm/s	0–40 cm/s	1 cm/s[c]–40 cm/s[d]
Juvenile velocity range	0–30 cm/s	0–40 cm/s	1 cm/s[c]–30 cm/s[e]

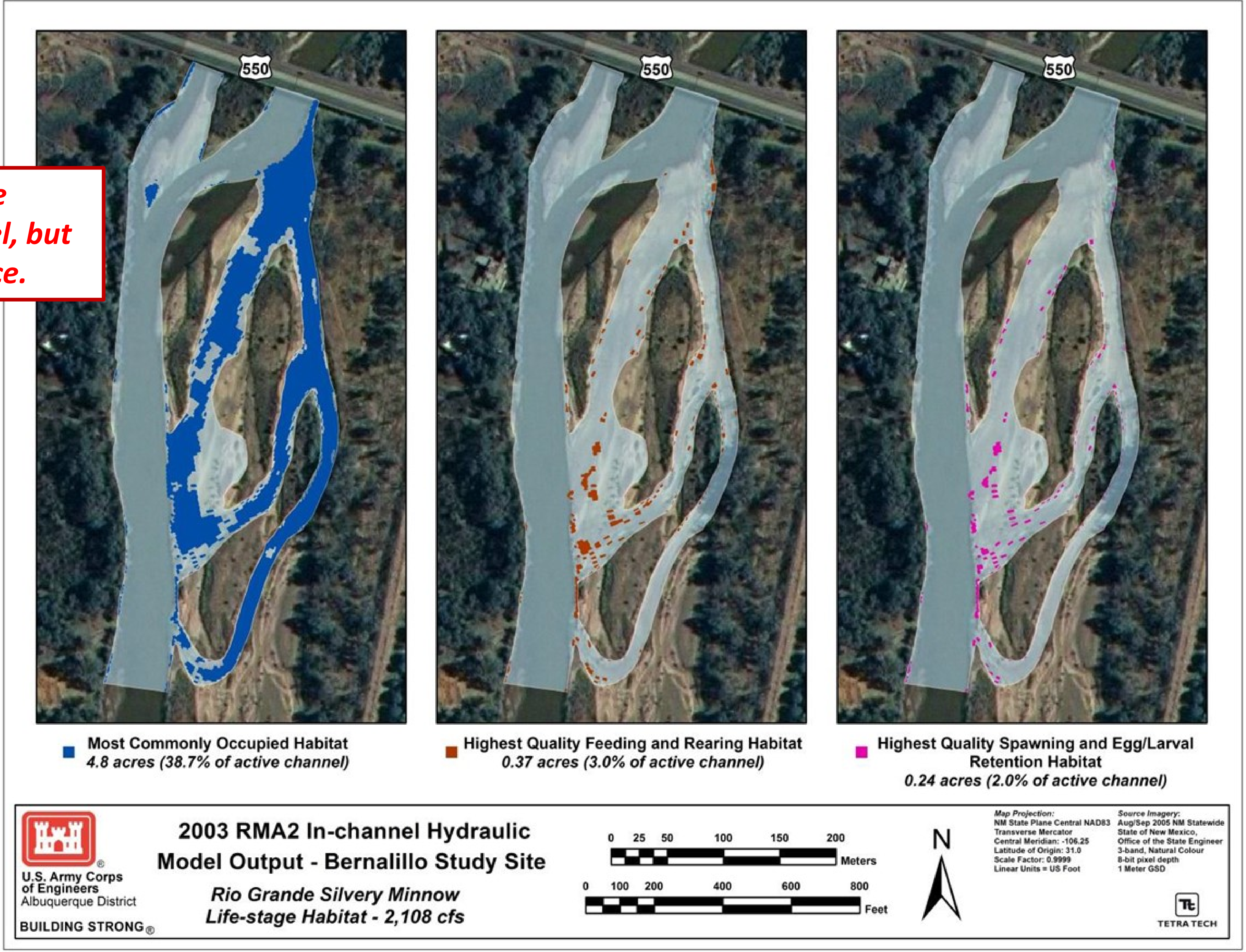
Justification for modifications:

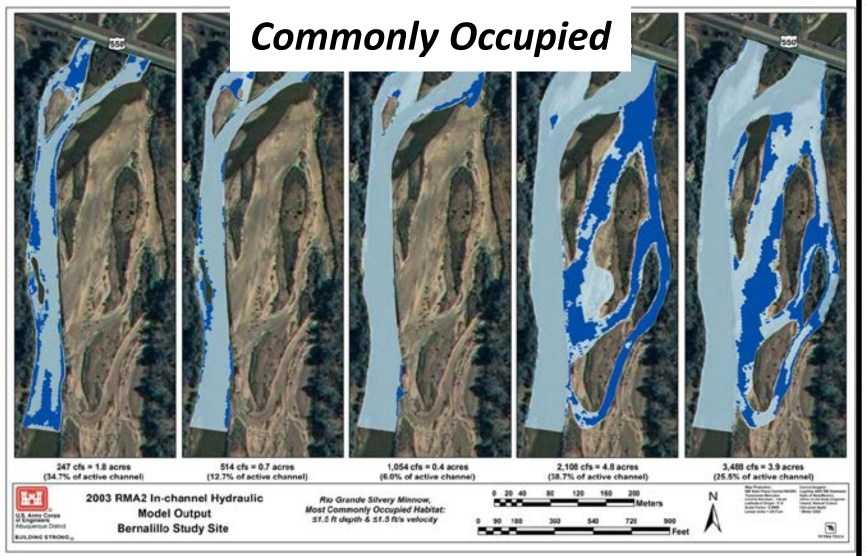
(a) Minimum depth set at 5 cm for habitat use at shallower depths consistent with feeding biology
(b) Maximum depth changed to 0.5 m for consistency with recovery plan
(c) Minimum velocity set at 1 cm/s to differentiate flowing water from stagnant pools
(d) Maximum velocity for adults reduced for consistency with recovery plan
(e) Maximum velocity for juveniles reduced from recovery plan to reflect sustained swimming performance of post-larval fish

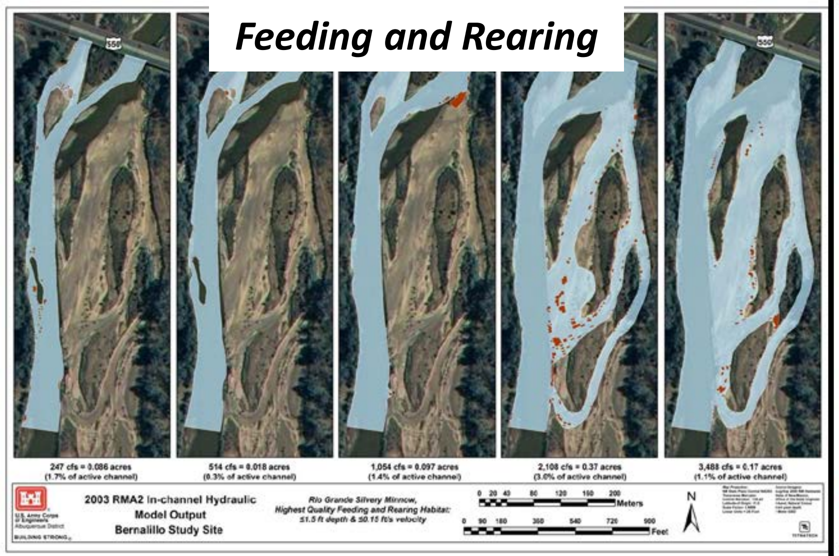
4c – TetraTech

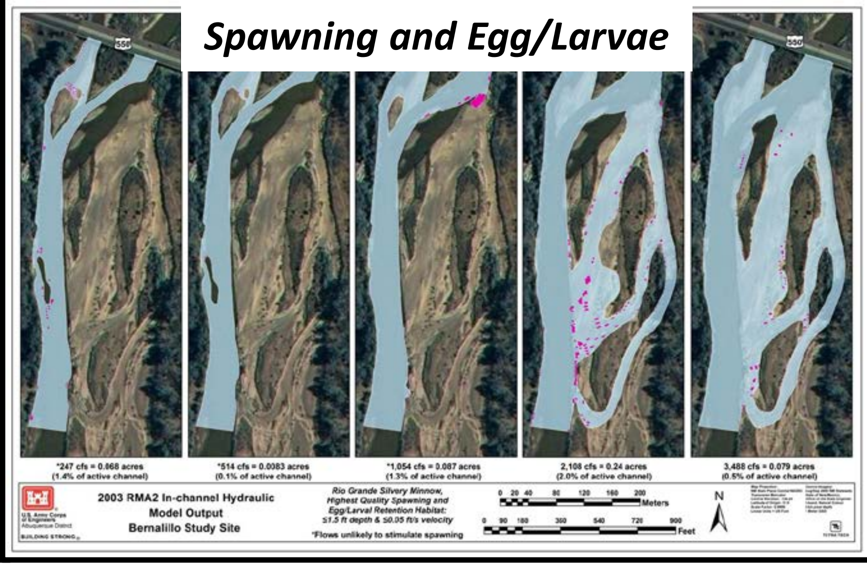
Habitat criteria are used to define suitable areas of the river channel, but are not linked to RGSM abundance.

1. Most Commonly Occupied Habitat
2. Highest Quality Feeding and Rearing Habitat
3. Highest Quality Spawning and Egg/Larval Retention Habitat

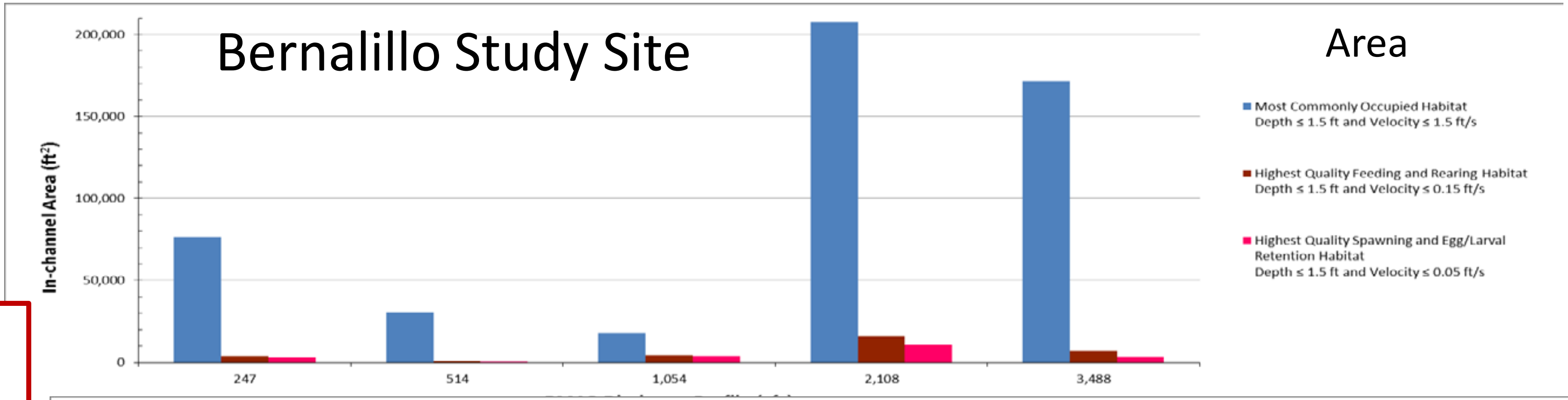






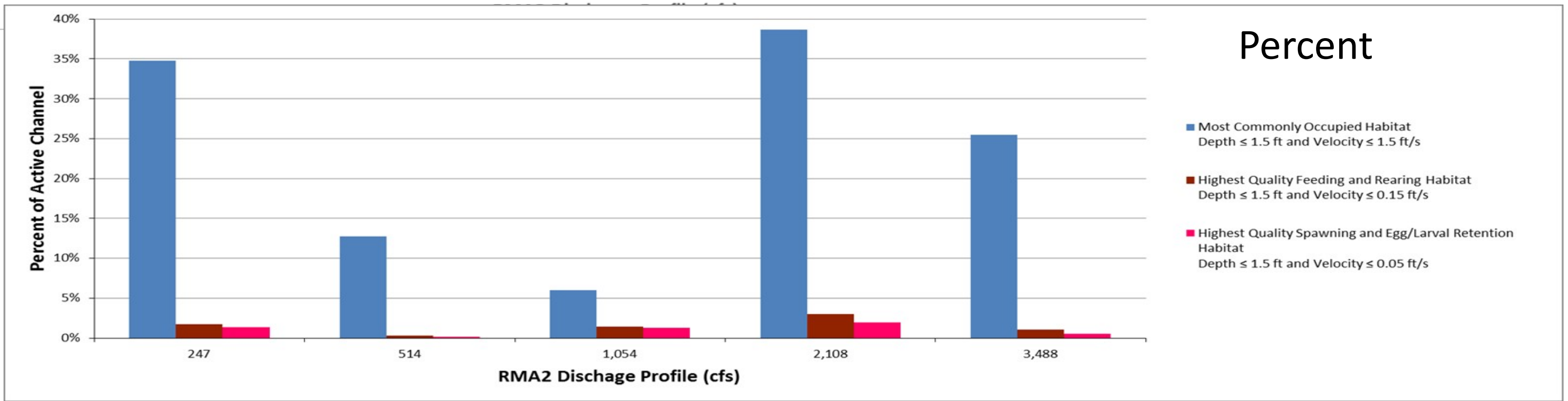


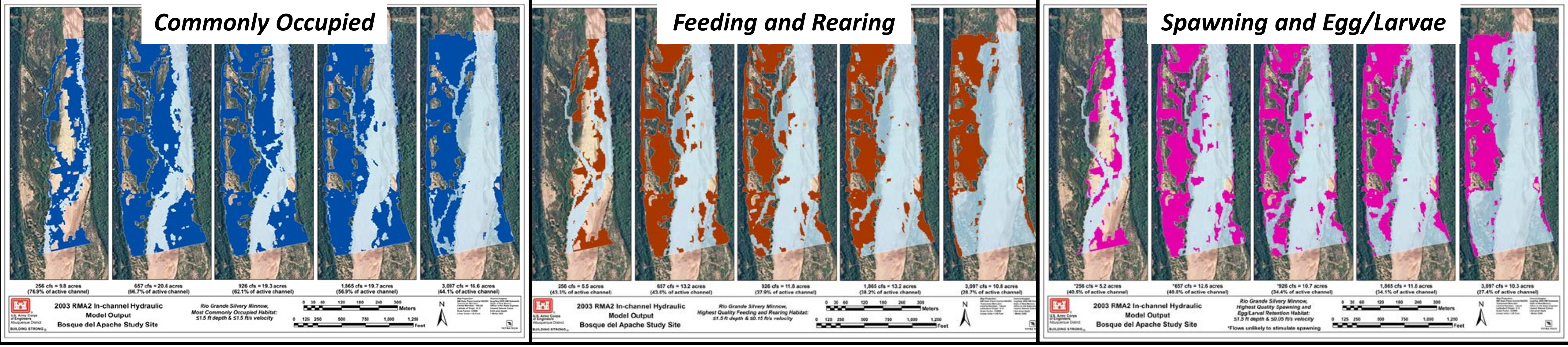
4d – TetraTech



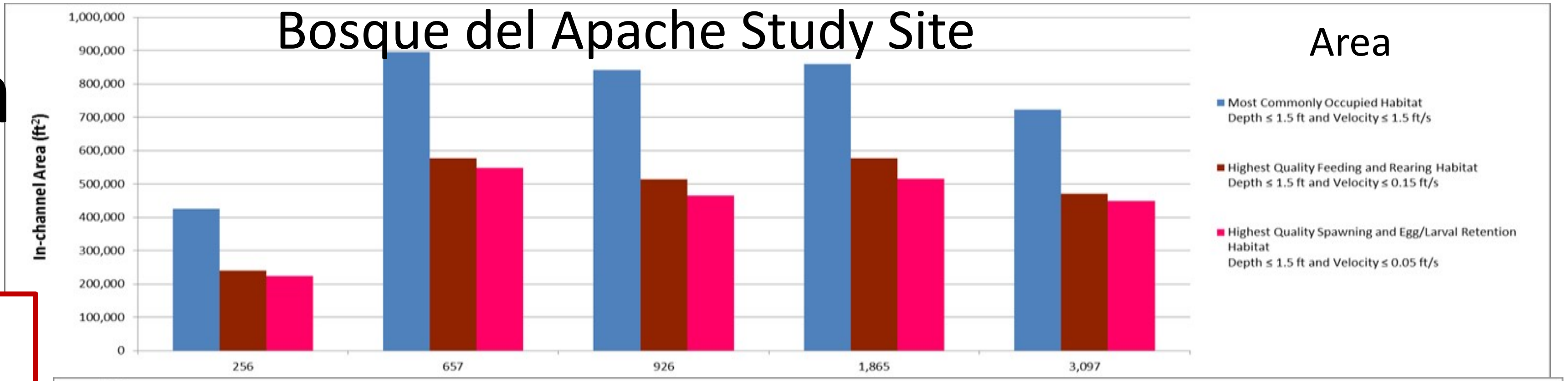
Habitat criteria are used to define suitable areas of the river channel, but are not linked to RGSM abundance.

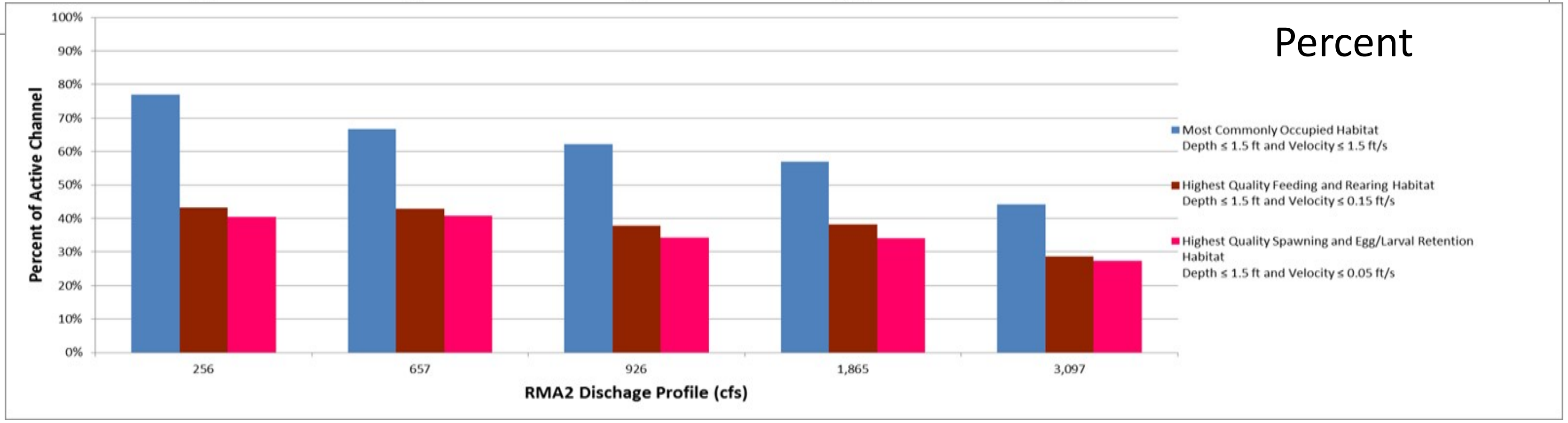
Big difference by Study Site!





4e – TetraTech





Habitat criteria are used to define suitable areas of the river channel, but are not linked to RGSM abundance.

Big difference by Study Site!

4f – TetraTech

Total capture of RGSM is provided, but not expanded to abundance, and not related to habitat or flow.

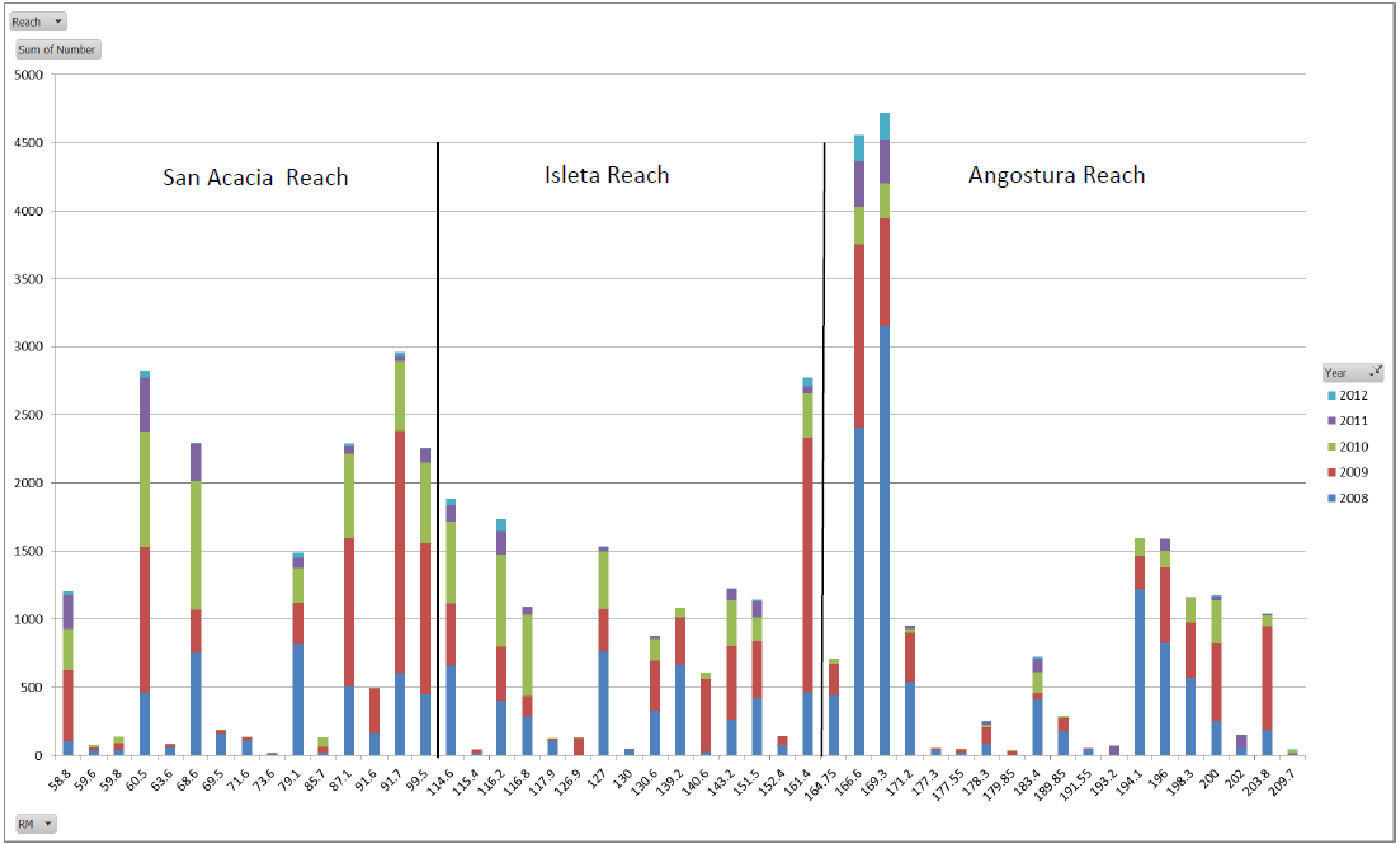


Exhibit C4. MRG Long-Term Monitoring Program total capture of Rio Grande silvery minnow by year and reach, 2008-2012.

5a – Braun

Braun et al. (2015)

- Objectives: Evaluated physical characteristics and fish assemblage composition of mesohabitats over a range of streamflows at 15 sites on the MRG (winter 2011–12 and summer 2012).

- Methods:
  - Wetted area, physical characteristics, and fish assemblage of river mesohabitats were characterized within a 1-km length of stream channel at each site (D, V, Temp, CO, pH, Cond).
  - Fifteen sites distributed along the MRG were selected starting 3 km downstream from Cochiti Dam and ending 40 km upstream of Elephant Butte Reservoir.
  - Sites grouped into four river reaches separated by diversion dams.
    - Cochiti (Peña Blanca),
    - Angostura (Bernalillo, La Orilla, Barelas, Los Padillas),
    - Isleta (Los Lunas I, Los Lunas II, Abeytas, La Joya, Rio Salado), and
    - San Acacia (Lemitar, Arroyo del Tajo, San Pedro, Bosque del Apache I, and Bosque del Apache II).

5b – Braun

- Mesohabitat assessment generally consists of three steps that together lead to conclusions regarding the effects of various management options.

- To assess mesohabitats, geospatial measurements (data associated with a particular location) are made as a first step to generate maps, which provide quantitative descriptions of the ecohydraulic habitat conditions in the river over a range of streamflows (that is, how the various mesohabitat types change under different streamflow conditions) (Bovee and others, 1998, 2008).

- The second and third steps include the collection of physical measurements and biological measurements, respectively, both of which are used to determine habitat use by selected fish species.

5c – Braun

Mesohabitat Types

Mesohabitat types modified from Platania (1993)—and Dudley et al. (2019).

Table 2. Description of mesohabitat types (modified from Platania, 1993) and channel features that were mapped on the Middle Rio Grande, New Mexico, 2011–12.

[ft/s, feet per second; ft, feet; NA, not applicable]

Mesohabitat type	Description	Velocity minimum to maximum (ft/s)	Depth minimum to maximum (ft)
Riffle	Relatively shallow and low to moderate velocity feature characterized by moderately turbulent water	-0.05–4.80	0.01–2.58
Run	Relatively high-velocity feature with laminar flow and a nonturbulent surface	-1.05–5.39	0.02–4.31
Pool	Feature with little or no velocity that may be deep in places	-2.14–1.70	0.04–4.40
(a) Channel	Type of pool where current moves in the same flow direction as the channel		
(b) Eddy	Type of pool where current moves in the opposite direction relative to flow		
Isolated pool	Type of pool that is separate from the main channel; frequently a portion of a former backwater or forewater that has become disconnected from a secondary channel	-0.06–0.21	0.01–2.40
Forewater	Slackwater feature oriented into the principal direction of flow	-0.10–0.08	0.01–1.00
Backwater	Slackwater feature oriented in an opposing direction to the principal flow direction	-0.23–2.25	0.01–2.87
Embayment	Slackwater feature located adjacent to the channel and oriented perpendicular to flow	-0.27–1.02	0.03–1.26
Flat	Very shallow, low-velocity feature typically located on the periphery of an existing point or channel bar; caused by a slight rise in stage	-0.62–3.13	0.01–2.4
Channel feature	**Description**		
Point bar	Crescent-shaped depositional feature located on the inside of a stream bend; typically either devoid of or containing annual vegetation	NA	NA
Channel bar	Transitory parcel of land surrounded by water; typically either devoid of or containing annual vegetation	NA	NA

5d – Braun

Mesohabitat types modified from Platania (1993)—and Dudley et al. (2019).

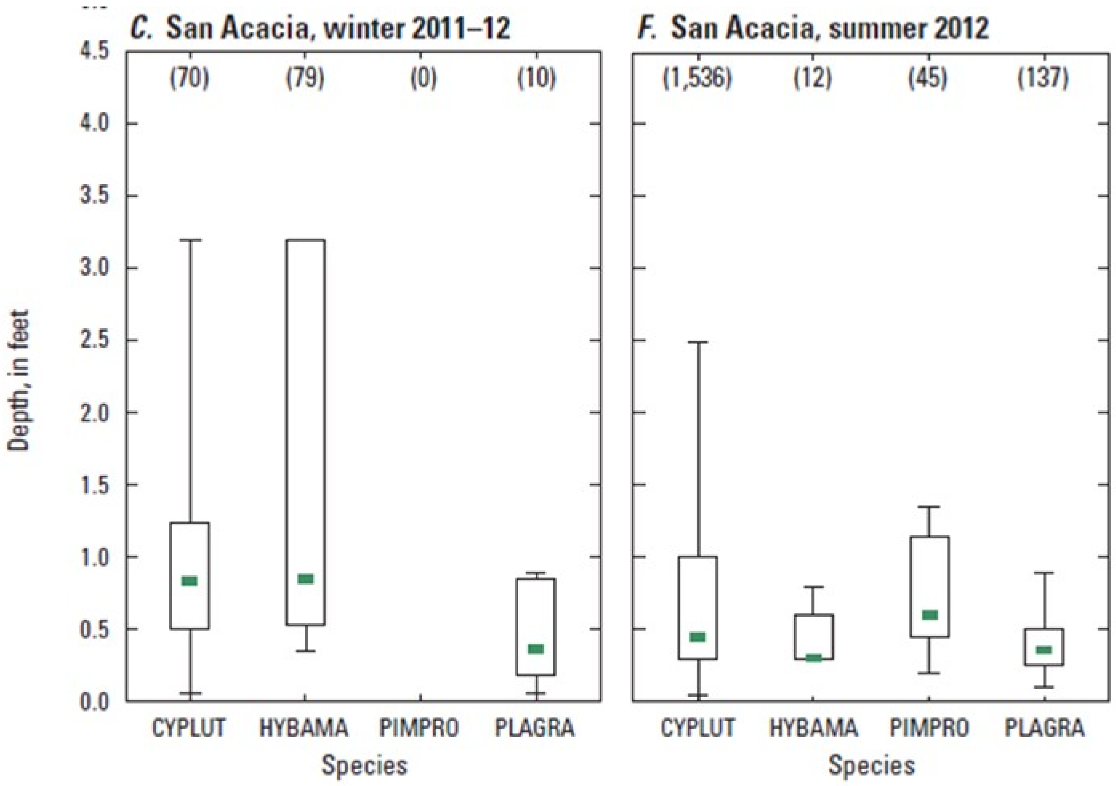


Figure 20. Depths associated with the collection of selected minnow species from three reaches of the Middle Rio Grande, New Mexico, during winter 2011–12 *A*, Angostura; *B*, Isleta; and *C*, San Acacia; and during summer 2012 *D*, Angostura; *E*, Isleta; and *F*, San Acacia.

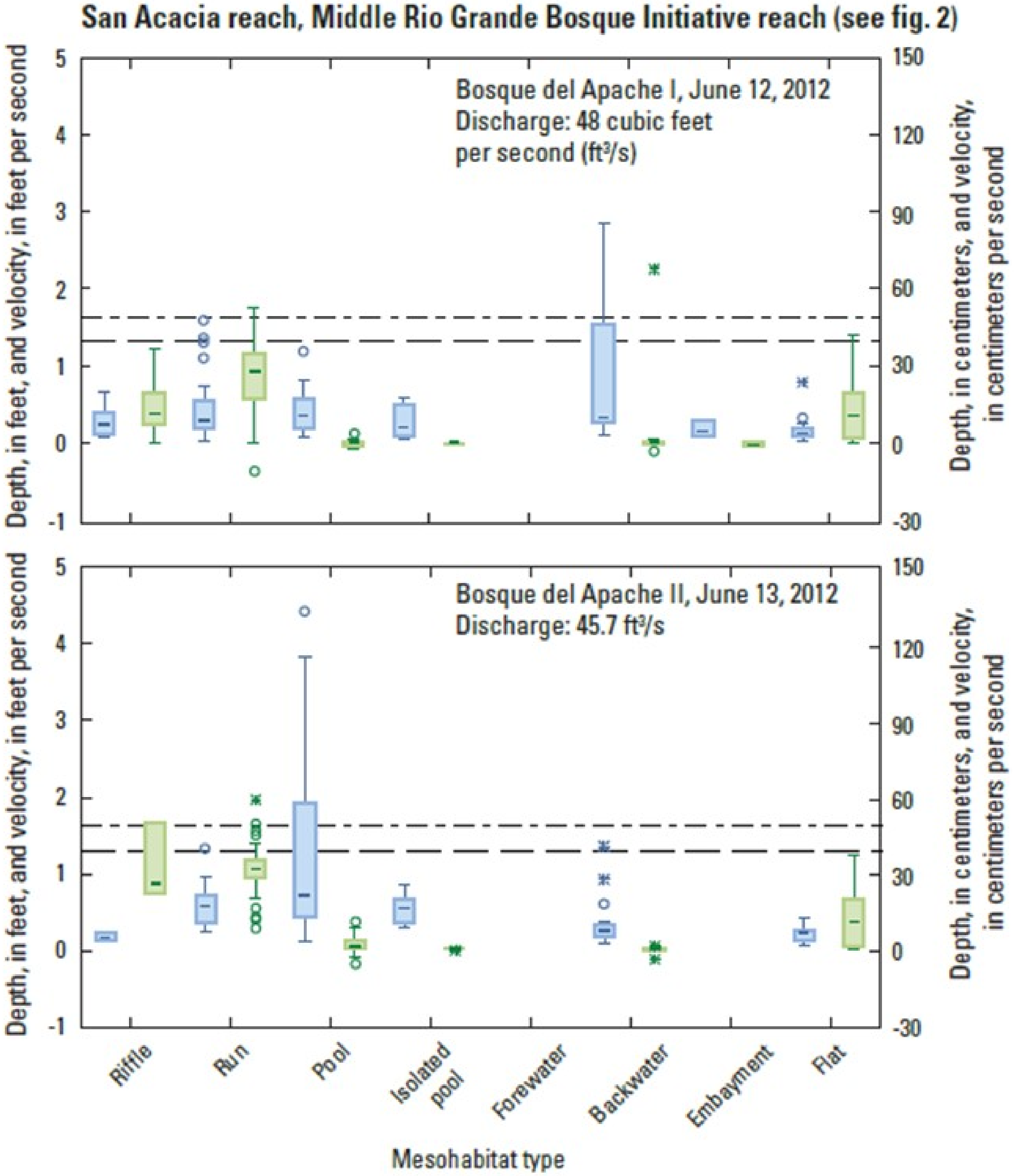
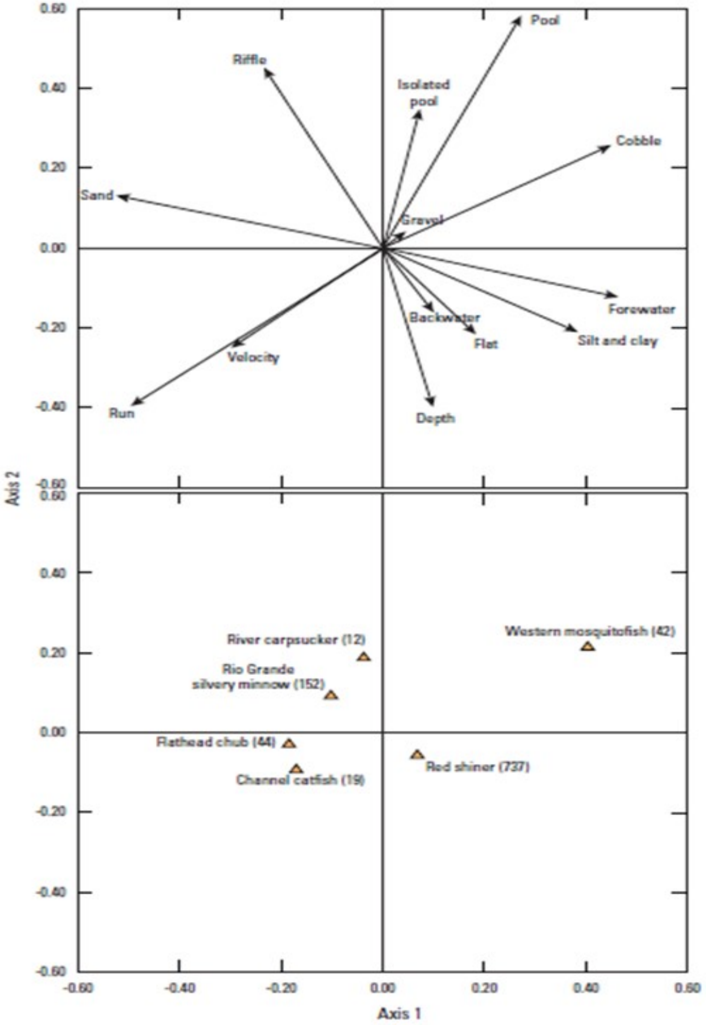


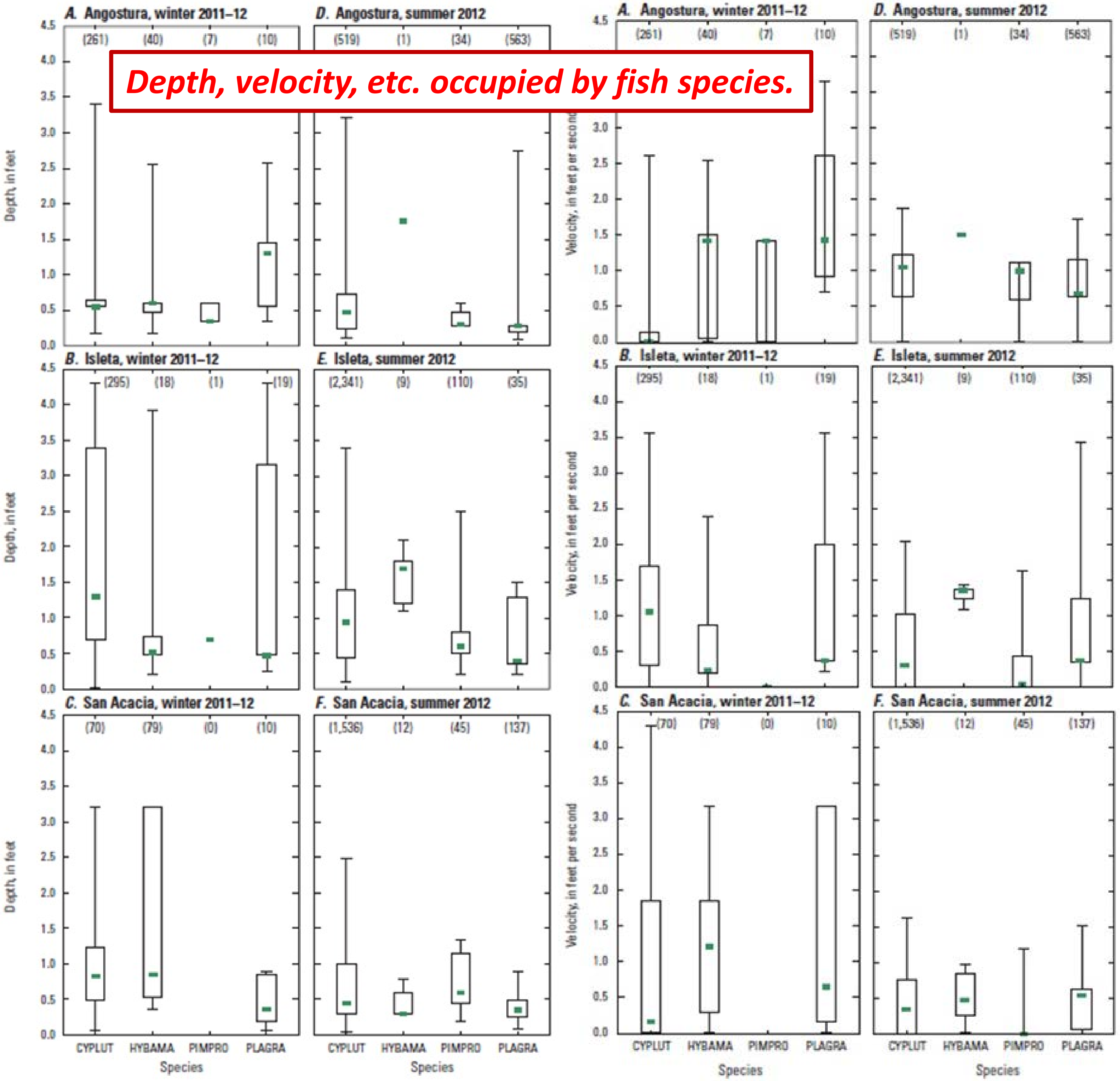
Figure 10. Depth and velocity in different mesohabitat types at 15 sites on the Middle Rio Grande, New Mexico, winter 2011–12 and summer 2012.

5e – Braun

PCA: Similarity of fish species to mesohabitat type and selected environmental variables.



Depth, velocity, etc. occupied by fish species.



6a – USFWS

USFWS (2016)—Appendix A, 2016 BiOp

- Objective:
  - Determine (or affirm) relationships between indices of RGSM population abundance estimates and occupancy distribution indices (Dudley et al. 2016) with measures river discharge and levels or areas of water inundation of the channel and associated floodplain in the MRG.
- Methods:
  - Hydrobiological analyses based on linear and polynomial relationships (scatterplots) between RGSM abundance and distribution indices and historical river flows, channel inundation areas, and other hydrological attributes and measurements collected annually.
  - Hydrobiological Objectives are recommendations for potential water management flow regimes according to historical information about duration, magnitude, and timing of spring runoff and areas of channel inundation that appear necessary to support survival and conservation of RGSM population in the MRG.

6b – USFWS

Same computation of Ne, MVP, and buffered MVP as used for 2002 Recovery Goals for four CPM, HBC, RBS, and BYT.

- Computation of a MVP for silvery minnow in the MRG:
- Ng = Ne/(Ne/Ng)
  - Where: Ne = genetic effective population size, 5,000
  - Ne/Ng = proportion of adults contributing genes to next generation; ~0.30 for most fish (Service 2002, their Table 2)
  - Therefore: Ng = 5000/0.30 (~assuming 30 percent successfully spawn)
  - Ng = 16,667, the minimum number of spawners in May
- Given our assumptions:
  - Estimated MVP is 16,667 individual spawners.
  - Used a modified analysis provided (Bui 2016) to estimate the average top width of MRG (Angostura Dam to RM 60 (253 km) during low flow (July through October) for three hydrologic scenarios (Very Wet, Average, Very Dry). (average area of ~ 49,202,405 m^2)
  - = 16,667 / 49,202.4 x 100m^2) = **0.3 fish per 100 m^2 (lowest density to protect against genetic inbreeding**.
  - Monthly rates of RGSM mortality from May to October varies substantially (Miller 2012), estimated density in October would be approximately 1.6 fish per 100 m^2.

6c – USFWS

Same computation of Ne, MVP, and buffered MVP as used for 2002 Recovery Goals for four CPM, HBC, RBS, and BYT.

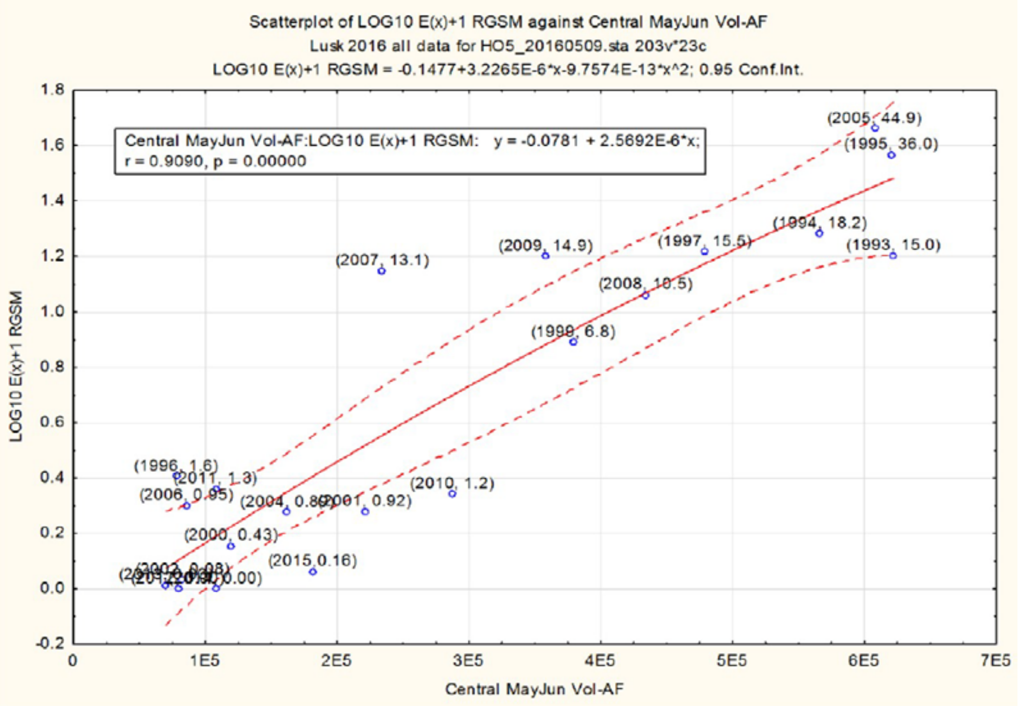
- MVP calculation does not reflect a density dependent population a mortality factor is added to estimate a genetically viable population.
- Modified annual mortality factor (Goodman (2012) and runoff rates (Very Dry =1.33; when the year is Average = 1.46, and if the years is Very Wet = 1.92), to develop a buffered MVP.
  - Very Dry Year buffered MVP = 16,667 x 1.33 = 22,167 adults
  - Average Year buffered MVP = 16,667 x 1.46 = 24,334 adults
  - Very Wet Year buffered MVP = 16,667 x 1.92 = 32,001 adults
- Buffered MVP population sizes ranged from 22,167 to 32,001 spawning adults that are estimated for May and June.
- Assumed 33 to 92% loss from previous May and June to October.
- Used modified analysis (Bui 2016) to estimate channel width of three river reaches during low flow conditions for the three hydrologic scenarios (Very Wet, Average, Very Dry).
  - For Very Wet years ~ 63,095,135 m^2 at maximum top width by its length from Angostura Dam until about RM 60 or 253 km (157 mi) and with an estimated density of (32,001 fish divided by 63,095.1x100m^2) = 0.8 fish per 100 m^2.
  - For Average type years, ~ 25,561.1 m^2 at maximum top width in the MRG with 24,404 RGSM, resulting in estimated density of (24,404 fish/25,561.1x100 m^2) of approximately 1.0 fish per 100 m^2.
  - For Very Dry years, ~ 20,635.7 m^2 at maximum top width in the MRG with 20,635 RGSM, resulting in estimated density of (20,635 fish/20,635.7x100 m2) of approximately 1.1 fish per 100 m^2.
  - Overall average of 32,001 fish in an average river width of 49,202,205 m^2, was 0.7 fish per 100 m^2. = **buffered MVP of ~ 1.0 fish per 100 m^2 to evaluate whether a self-sustaining population was achieved**.

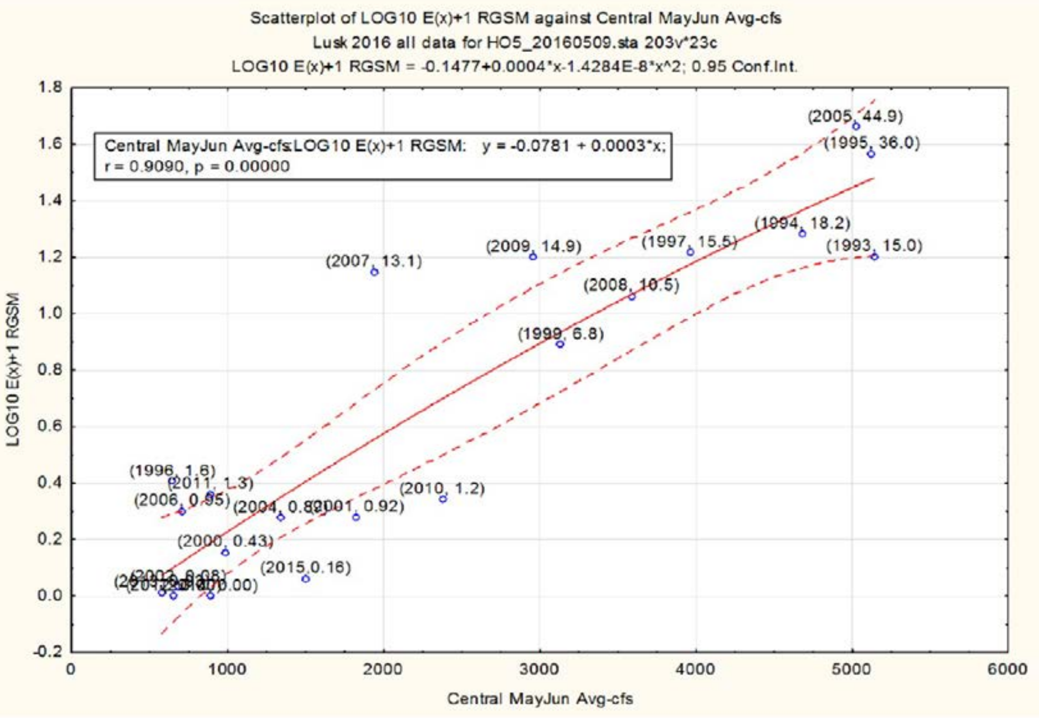
6d – USFWS

Relates total numbers of RGSM to flow. ***(being evaluated by Budy and Walsworth (2019)***

Table A3. Relationship between the volume (in acre-feet) crossing the ABQ-Central Gage during May and June and the estimated abundance density of silvery minnows in fall (transformed base 10 logarithms of estimated October silvery minnow abundance densities ((E(x)) ~fish per 100 m^2 + 1)(Dudley et al. 2016).

May and June Runoff Volume (in acre-feet) at ABQ-Central Gage	Y-axis value (log10 E(x) + 1) for silvery minnow abundance model in Figure 1	Estimated silvery minnow abundance in fall using a polynomial model (Estimated October abundance E(x) = fish per 100 m^2+1)	Estimated silvery minnow abundance in fall using a LINEAR model (Estimated October abundance E(x) = fish per 100 m^2+1)
20,000	-0.08	-0.2	-0.1
40,000	-0.02	0.0	0.1
60,000	0.04	0.1	0.2
80,000	0.10	0.3	0.3
100,000	0.17	0.5	0.5
120,000	0.23	0.7	0.7
145,000	0.30	1.0	1.0
165,000	0.36	1.3	1.2
180,000	0.40	1.5	1.4
200,000	0.46	1.9	1.7
220,000	0.51	2.3	2.1
251,500	0.60	3.0	2.7
260,000	0.63	3.2	2.9
280,000	0.68	3.8	3.4
295,000	0.72	4.2	3.8
318,000	0.78	5.0	4.5
332,000	0.82	5.5	5.0
360,000	0.89	6.7	6.0
380,000	0.94	7.7	6.9
400,000	0.99	8.7	7.9
420,000	1.04	9.8	9.0
440,000	1.08	11.1	10.3
460,000	1.13	12.5	11.7
480,000	1.18	14.0	13.3
500,000	1.22	15.7	15.1





7a – Yang

Yang et al. (2018) – Objectives

- Delineate Isleta Reach into six subreaches.
- Use historic flow and sediment discharge.
- Compare RGSM population to peak discharges.
- Analyze geomorphological drivers at a subreach level (sinuosity, width, braiding, bed elevation, bed material, volume change, and hydraulic parameters).
- Create a conceptual geomorphic model to help predict how the river will change in the future
- Analyze how RGSM habitat changes with different flow regimes.
- Analyze habitat quality of RGSM with remote sensing (GIS).

Figure 1: Map of Isleta Reach and location of breaks of subreach.

7b – Yang

- Analyzed amount of “inadequate”, “adequate”, “good”, “feeding/ rearing”, and “spawning” habitat.

- By looking at simulated velocities and depths at range of flows, we have insight into RGSM habitat and how it changes with different flow regimes, spatially, and temporally.

- HEC-RAS is employed to analyze the hydraulic condition at different flow conditions.

- Flows used in HEC-RAS were based on past analyses and practicality; e.g., 25-day exceedance spring runoff peak flow for dry, mean, and wet year are identified by MEI (2006) to be 1400, 3500, and 5600 cfs, respectively.

7c – Yang

Yang et al. (2018)

The classification of habitat for silvery minnow used in this section is based on criteria and descriptions of habitat from Tetra Tech (2014).

Note: these are the criteria developed by Bovee et al. (2008) and also used by Tetra Tech (2014)

Table 9: Habitat Classification based on flow depth and velocity

Depth (ft)	Velocity (ft/s)			
	0 – 0.05	0.05 – 0.5	0.5 – 1.5	> 1.5
0 - 1.5	Spawning	Feeding/rearing	Good	Inadequate
1.5 – 1.6	Adequate	Adequate	Adequate	Inadequate
>1.6	Inadequate	Inadequate	Inadequate	Inadequate

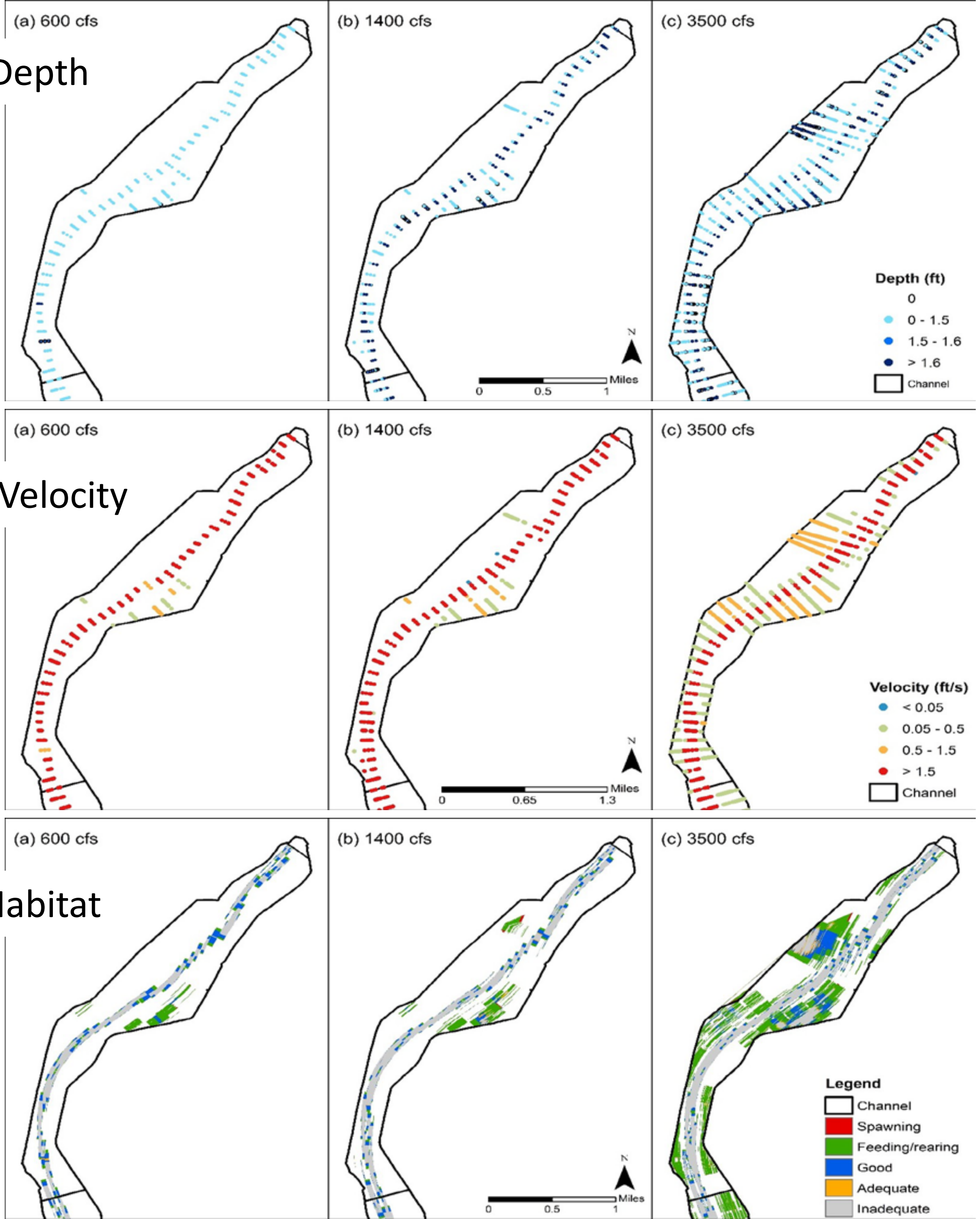
7d – Yang

Simulated depth, velocity, hydraulic habitat determined for 6 subreaches in Isleta Reach, but not related directly to fish abundance.

Simulated Depth

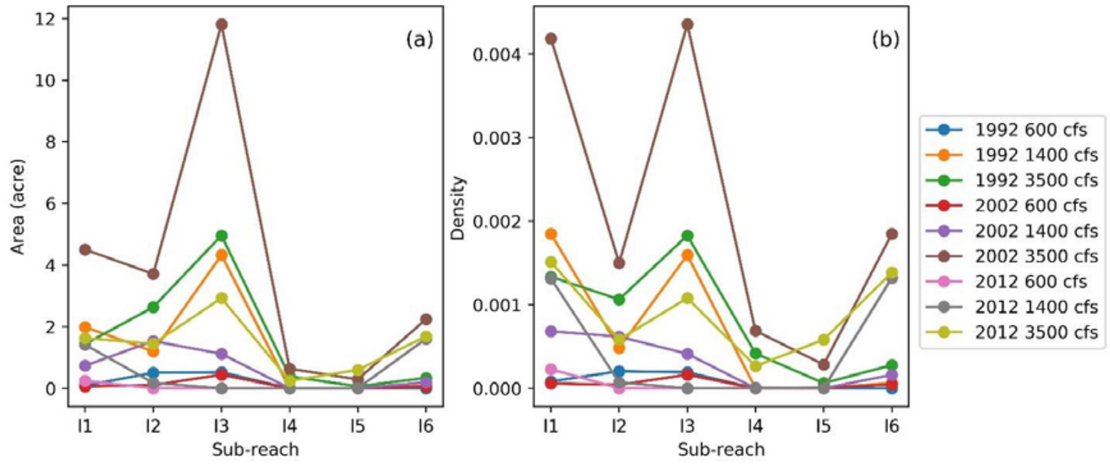
Simulated Velocity

Hydraulic Habitat



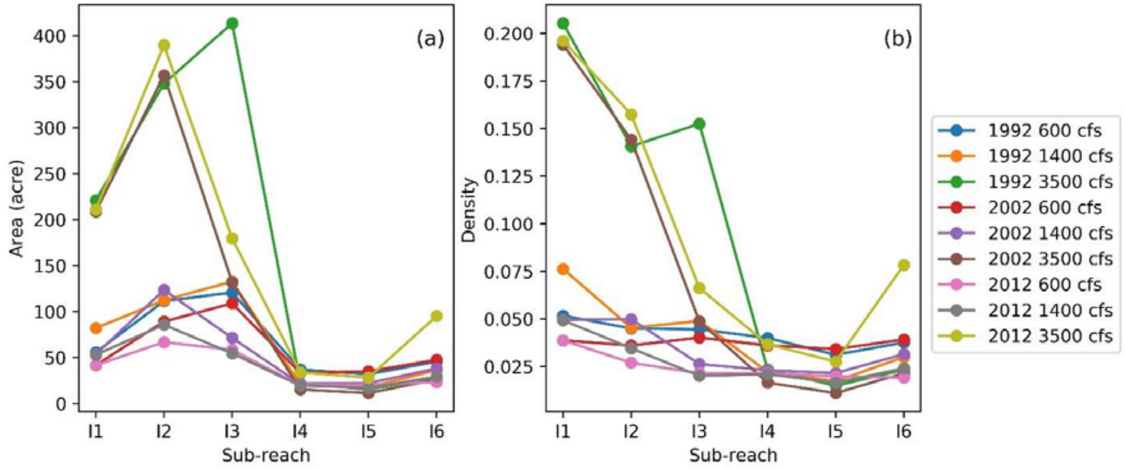
7e – Yang

Spawning Habitat

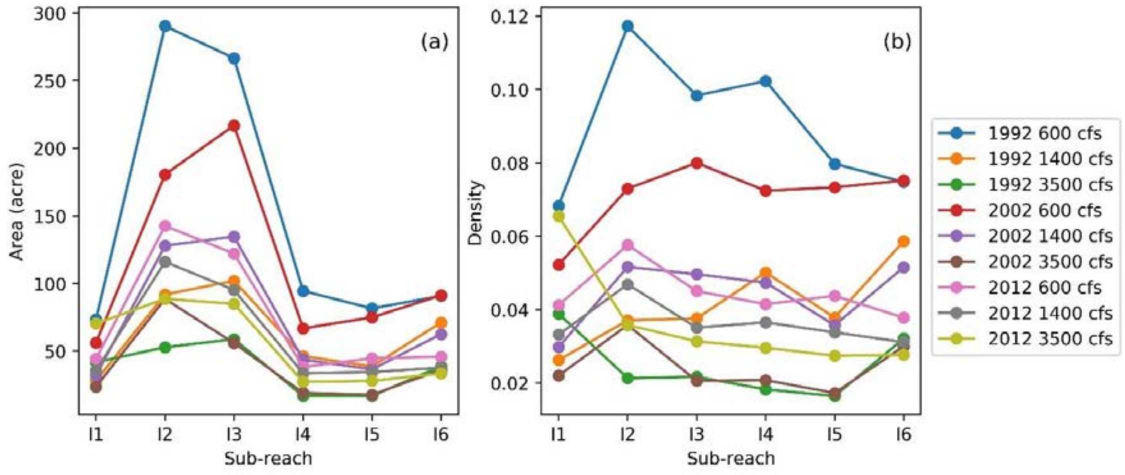


Spawning, feeding/rearing, and good habitat determined for 6 subreaches in Isleta Reach, but not related directly to fish abundance.

Feeding/Rearing Habitat



"Good" Habitat

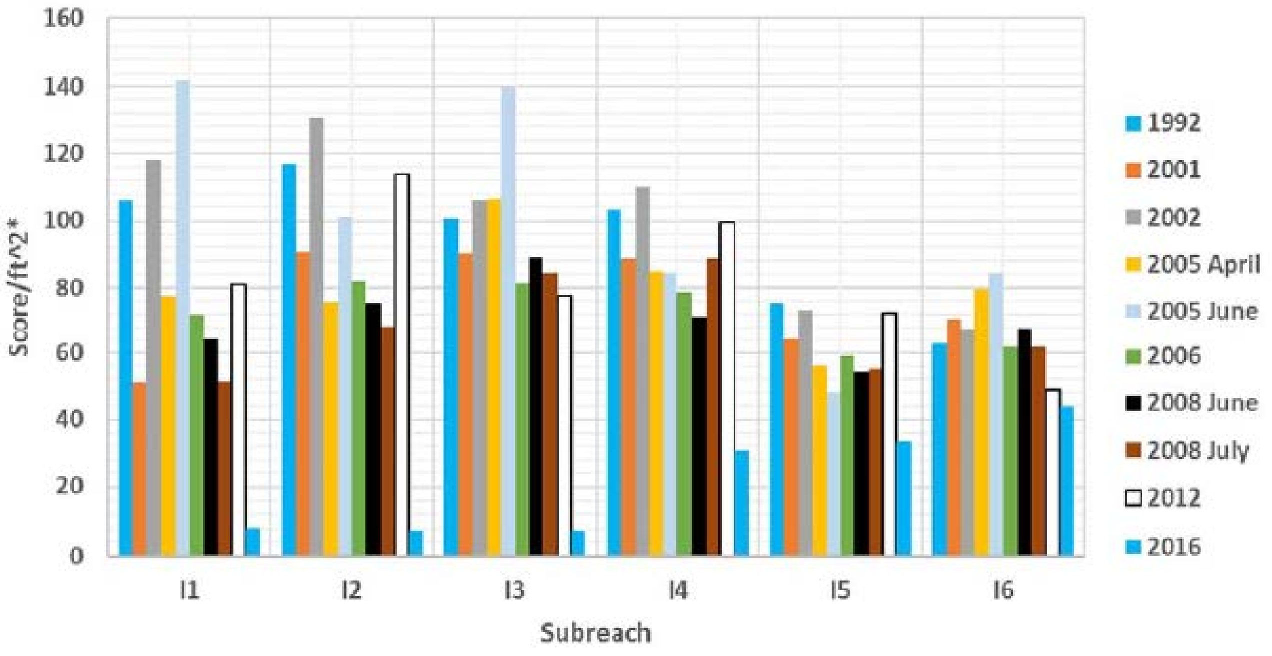


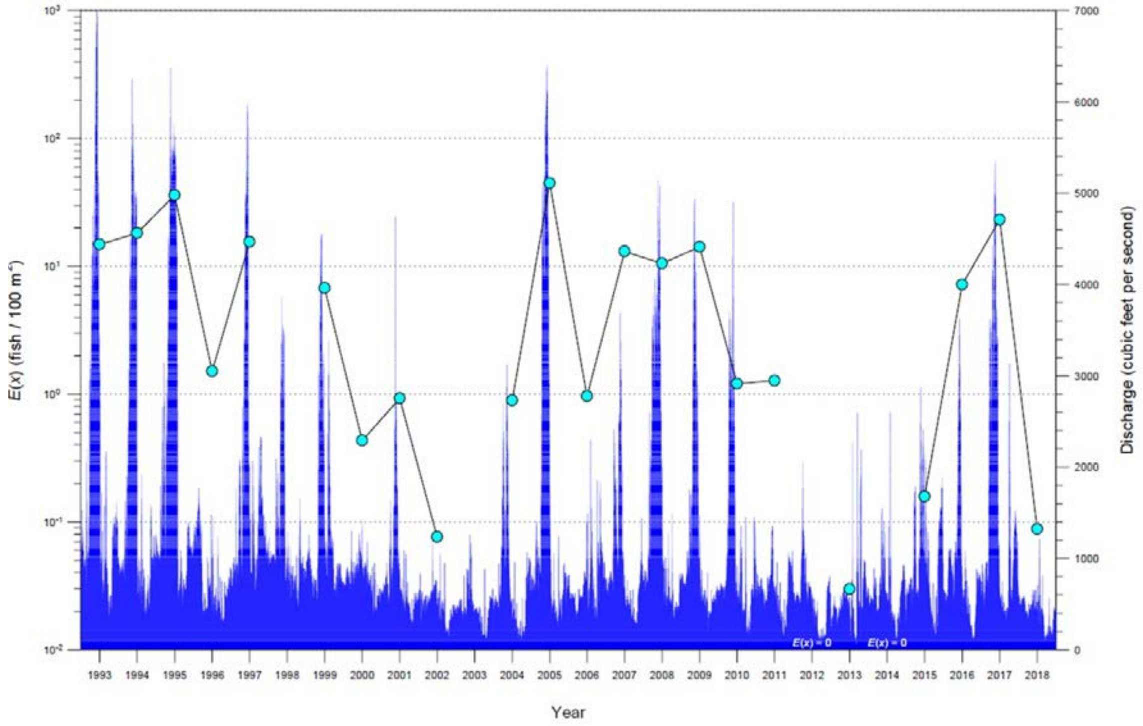
7f – Yang

- "…1992 and 2002 have better habitat than 2006 and 2012. This makes sense because habitat quality for silvery minnows in the Middle Rio Grande has been decreasing over time (Scurlock 1998; Bovee et al. 2008; Tetra Tech 2014)." ***Does not correspond with mean annual CPUE.***

- "When comparing all the years 2002, June and April of 2005, and 1992 consistently have the highest scores. 2006, July of 2008 and 2016 generally have the lowest scores. By subreach, I1-I3 have the highest scores for these years." ***Corresponds with high CPUE in 2005, but not 2002—or with 2008 and 2016 with moderate to high CPUE.***

- "2016 has the lowest score by far because the river is dry for a lot of this reach, so it provides minimal habitat for silvery minnows. June of 2005 has the highest score mostly likely because of its high flow. By looking at the aerial photography, it is evident that the floodplain is inundated." ***Corresponds with 2005 with high CPUE, but not with 2016, which had a moderate CPUE.***





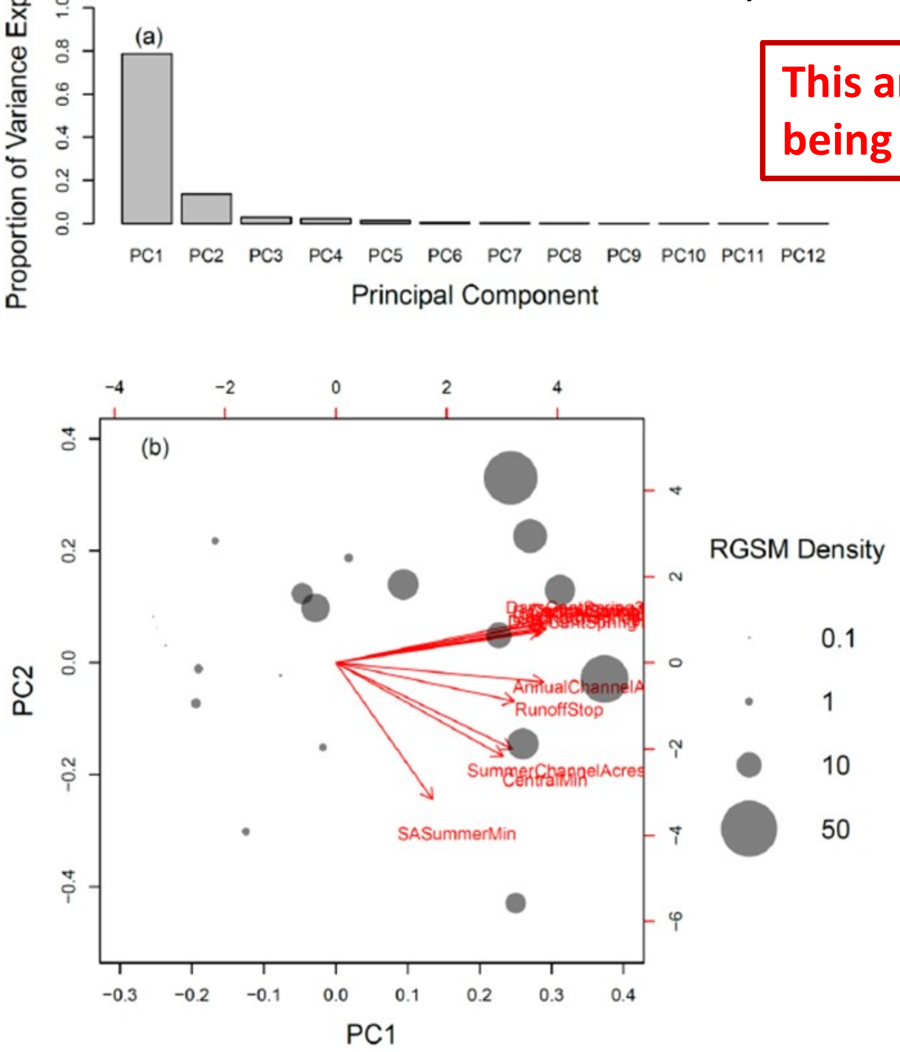
8a – Budy and Walsworth

Budy and Walsworth (2019)

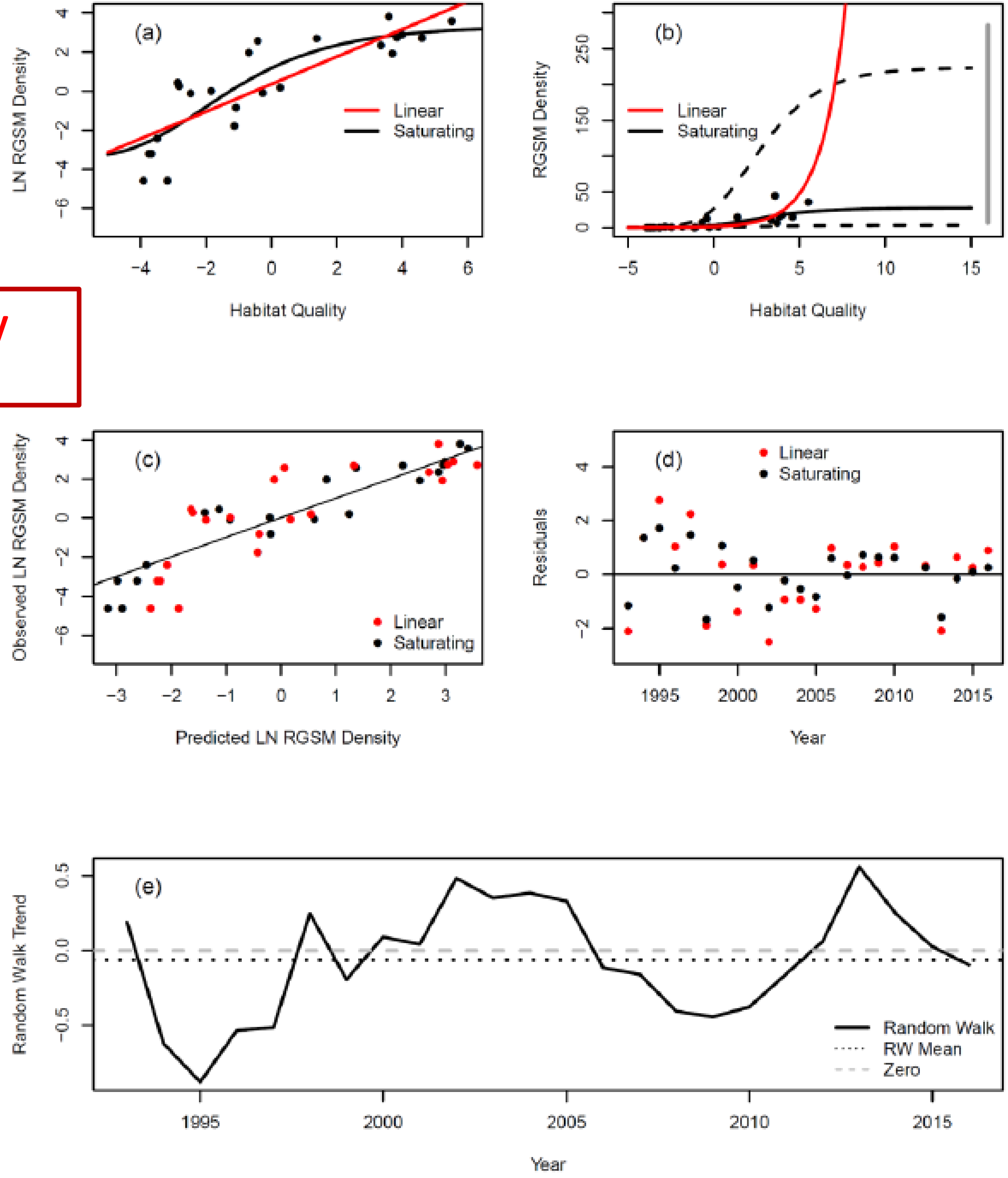
- This review was initiated to support the refinement of analyses and recommendations from the HBO, as new information has continued to be collected and the report and analyses in the Appendix had yet to be externally reviewed.
- The overall goal of this assessment is to review the HBO analyses and associated spreadsheet models to provide recommendations for refining the analyses and identifying data gaps.
- This review comprises the first of three potential phases, where the second phase may involve refining the models used to assess the impacts of hydrology on RGSM, and the third phase may involve providing tools for adaptive management.

8b – Budy and Walsworth

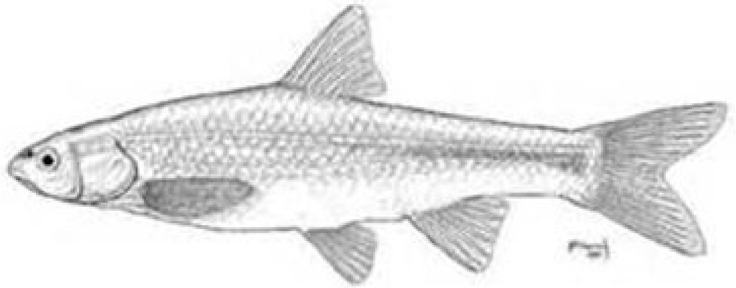
- PCA with 13 variables
- PC1 used as "Habitat Quality"



This analysis is currently being conducted.



Findings



- No study provides a direct relationship between flow, habitat, and RGSM total numbers.

- One study provides a direct relationship between flow and RGSM total numbers, derived from CPUE to flow relationships.

- 4 of 8 studies provide direct relationship of habitat to flow (RGSM abundance is inferred by habitat area and quality).

- 4 of 8 studies utilize the RGSM Habitat Criteria (depth, velocity) developed by Bovee et al. (2008) using a consensus Delphi process.

Preliminary –Revised

Overview of Flow, Habitat, and RGSM Abundance

Rich Valdez

Population Monitoring Workgroup Meeting

Albuquerque, NM

November 6, 2019

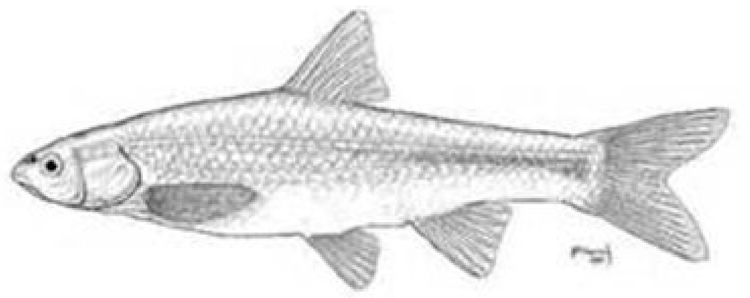
The Issue:

The abundance parameter is vital to an integrated model.

There is a need to quantify total RGSM abundance as related to habitat and flow

- Abundance is defined as total number of individuals in the population (not CPUE)

Purpose for this Overview



- To assimilate and review relevant literature.
- To initiate a conversation of the PMWG.
- To reconcile the relationship of flow, habitat, and RGSM abundance.

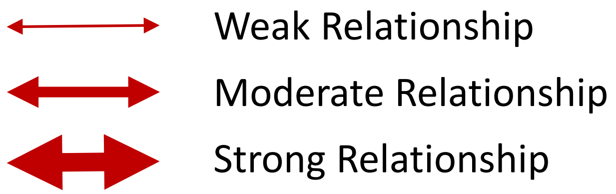
Key Documents—Flow, Habitat, and RGSM Abundance

1. Remshardt, W.J., and P.L. Tashjian. 2003. Habitat preference of Rio Grande silvery minnow in relation to fluvial geomorphology, and flow regime, Middle Rio Grande Valley, New Mexico. Interim Report for Funding Year 2003. U.S. Fish and Wildlife Service, Albuquerque, NM.
2. Bovee, K.D., T.J. Waddle, and J.M. Spears. 2008. Streamflow and endangered species habitat in the lower Isleta reach of the Middle Rio Grande. US Geological Survey, Open-File Report 2008-1323.
3. Stone, M.C. 2008. Physical habitat model for the Rio Grande silvery minnow. World Environmental and Water Resources Congress 2008: Ahupua'a. American Society of Civil Engineers.
4. Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2011, 2012. Rio Grande silvery minnow population estimation program results from October 2010 (2011). Final Report. American Southwest Ichthyological Researchers, L.L.C., Albuquerque, NM.
5. Miller, P.S. 2012. A RAMAS-Based Population Viability Model for the Rio Grande silvery minnow (*Hybognathus amarus*). Final Report, Middle Rio Grande Endangered Species Act Collaborative Program, Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN.
6. Tetra Tech, Inc. 2014. Ecohydrological relationships along the Middle Rio Grande of New Mexico for the endangered Rio Grande silvery minnow. Final Report, Contract WP912PP-08-D-0009-0-20, Task Order 20, Task 5. U.S. Army Corps of Engineers, Albuquerque District, Albuquerque, NM.
7. Braun, C.L., D.K. Pearson, M.D. Porter, and J.B. Moring. 2015. Physical characteristics and fish assemblage composition at site and mesohabitat scales over a range of streamflows in the Middle Rio Grande, New Mexico, Winter 2011–12, Summer 2012. U.S. Geological Survey, Investigations Report 2015–5025. U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service, Albuquerque, NM.
8. U.S. Fish and Wildlife Service. 2016. Appendix A: Analytical framework for evaluating the proposed water management and maintenance actions on Rio Grande silvery minnow, southwestern willow flycatcher, and yellow-billed cuckoo and their critical habitats. Final Biological and Conference Opinion for Bureau of Reclamation, Bureau of Indian Affairs, and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico, Consultation Number 02ENNM00-2013-F-0033, U.S. Fish and Wildlife Service, Albuquerque, NM.
9. Harris, A., J. Bachus, E. Gonzales, and N. Holste. 2018. 2-D Hydraulic modeling to visualize aquatic fishery habitat (Rio Grande Silvery Minnow) with a suitability index. U.S. Bureau of Reclamation, Albuquerque Area Office, Technical Services Division, Albuquerque, NM.
10. Yang, Y., K. LaForge, and P. Julien. 2018. Middle Rio Grande—Isleta Reach: Isleta Diversion Dam to Rio Puerco, hydraulic modeling and silvery minnow habitat analysis, 1918-2016. Draft Report, August 2018, Prepared for: U.S. Bureau of Reclamation, Colorado State University, Engineering Research Center, Department of Civil Engineering, Fort Collins, CO.
11. Budy, P., and T.E. Walsworth. 2019. Review of the "Analytical framework for evaluating the proposed water management and maintenance actions on Rio Grande silvery minnow, southwestern willow flycatcher, and yellow-billed cuckoo and their critical habitats" with recommendations for future analytical considerations. USGS Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, UT.

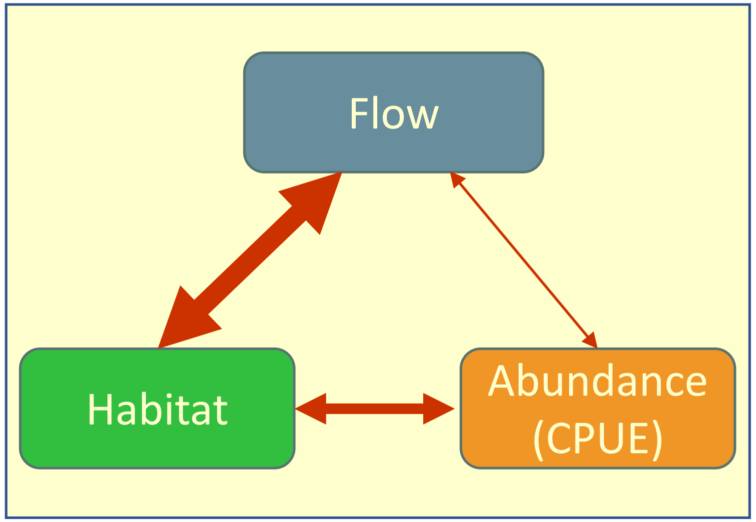
Source	Purpose	Sites	Tools (models)	Parameters	Results	Conclusion
1.Remshardt and Tashjian (2003)	Describe habitat use and investigate variation related to fluvial geomorphology and flow	10 (Bernalillo to BDA)	Cross sections at low (< 100 cfs), mid (100-750 cfs) high (750-4000 cfs); FLO 2D (Tetra Tech 2004); concurrent fish seining	Depth, velocity, mesohabitat from cs and seines; similar to 1-D PHABSIM	Flow vs shoreline complexity, preferred habitat, channel width	Best habitat in Sevilleta and Socorro reaches; second in Isleta reach; poorest in Albuquerque reach
2. Bovee et al. (2008)	Quantify changes in low flow habitat features from ~150 cfs into "Bernardo Siphon" near SADD	3 (10-mile reach between Lower San Juan Riverside Drain and SADD)	2-D PHABSIM	Depth, velocity in 2-D; large woody debris; parameters from **Delphi with expert panel**	Weighted Useable Area (WUA) for YOY, adult	Diversions to Bernardo siphon resulted in substantial increases to suitable habitat for both life stages (YOY, adult)
3. Stone, M.C. (2008)	Develop a habitat evaluation model to evaluate habitat suitability under unsteady flow conditions, near Albuquerque	1 (3-km reach from Alameda Boulevard bridge to Paseo Del Norte bridge)	CCHE2D hydrodynamic and sediment transport model (National Center for Computational Hydroscience and Engineering, Univ. of Mississippi)	Depth, velocity, mesohabitat from "Habitat Use of the Rio Grande Silvery Minnow" (Dudley and Platania, 1997)	Velocity and habitat suitability (HIS) for low and high flows; emphasize availability and fragmentation of overbank habitats	Flows less than bankfull, high quality habitat in regions with low velocity and high complexity (wakes of sandbars and in backwaters); overall habitat quality reduced as flow increased towards bankfull; above bankfull, high quality habitat shifted to the floodplains
4. Tetra Tech (2014)	Develop reach-wide baseline evaluation of habitat availability and quality to determine state of system along the San Acacia Reach	5 (Bernalillo to San Marcial)	Flow from URGWOPS; depth and velocity from RMA2 hydrodynamic model; Thiessen polygons in ArcGIS 10.1 (ESRI 2013); floodplain inundation from a FLO-2D	Depth, velocity of RGSM from **Delphi with expert panel** (Bovee et al. 2008)	Maps with polygons showing (1) most commonly occupied habitat, (2) feeding and rearing habitat, (3) spawning and egg/larval retention habitat	1,500-2,000 cfs for 7 days (~21,000- 28,000 AF) as minimum for producing a successful spring spawn with population recruitment in Albuquerque Reach; maintaining 100 cfs through Isleta reach (~200 AF per day) plus 600 AF for conveyance losses, surface evaporation, total ~800 AF per day
5. Braun et al. (2015)	Evaluate summer and winter physical characteristics and fish assemblage composition of mesohabitats over a range of flows (2011-2012)	15 (Cochiti Dam to Elephant Butte Reservoir)	Mapped polygons from geospatial database	Depth, velocity, substrate, embeddedness on transects; mesohabitat mapped at each site	Depth, velocity by mesohabitat type by site	Highest mean CPUE in isolated pools and lowest in flats, in summer and winter; RGSM occurred in narrowest range of depths (0.30–2.1 ft) during summer 2012, and narrowest range of velocities in both winter 2011–12 (0.0– 3.18 ft/s) and summer 2012
6. Yang et al. (2018)	Better understand link of morphodynamic processes and RGSM habitat	6 subreaches (Isleta Reach)	GIS analysis of aerial photographs (1918-2018); HEC-RAS analyses to show geomorphic changes	Depth, velocity; RGSM habitat criteria from **Delphi with expert panel** (Bovee et al. 2008) and also used by Tetra Tech (2014)	Analyzed amount of "inadequate", "adequate", "good", "feeding/ rearing", and "spawning" habitat	Current channel width less than 1/5 since 1918; slight increase in sinuosity, depth, velocity, and median grain size, while slope has decreased from 1972-2012; decrease in habitat quality due to: (1) a reduction in frequency and magnitude of peak discharges; and (2) channel narrowing and incising causing a loss of connectivity to floodplain
7. Harris et al. (2018)	Evaluate engineering design for pilot realignment of Rio Grande channel through the Bosque del Apache National Wildlife Refuge (BDA)	1 (3-mile reach at BDA where sediment plugs have previously formed)	HEC-RAS 5.0 to perform 2D hydrodynamic routing that produces detailed 2D channel and floodplain analysis (USACE 2016)	Depth, velocity; RGSM habitat criteria from **Delphi with expert panel** (Bovee et al. 2008) and also used by Tetra Tech (2014) and Yang et al. (2018)	(1) Ideal Habitat (meets both target ranges for depth and velocity); (2) Suitable Habitat (within maximum limits for depth and velocity; (3) Unsuitable Habitat (where wetted areas disconnected from river channel)	HSI modeling results demonstrate anticipated improvements to aquatic fish habitat resulting from the BDA Pilot Project

Source	Purpose	Sites	Tools (models)	Parameters	Results	Conclusion
1. Dudley et al. (2011, 2012)	Estimate numbers of RGSM by reach and total in the MRG. Quantify relationship of RGSM CPUE to total numbers	20 (5 Angostura, 6 Isleta, 9 San Acacia reaches)	Used multiple depletion estimator by electrofishing within enclosures by mesohabitat	Mesohabitat capture probability	RGSM population size calculated from Oct Population Estimation and Population Monitoring data by reach and for all reaches combined for 2008-2011	Total Number RGSM all reaches (unmarked, all ages): 2008: 1,108,430 2009: 1,387,948 2010: 267,272 2011: 122,381
2. Miller, P.S. (2012)	Develop a Population Viability Analysis (PVA) to evaluate extinction probability of RGSM under various environmental correlates (e.g., flow)	Based on 20 sites from Dudley et al. (2012)	RAMAS-Metapop (Akçakaya 2005) simulation model	Stock assessment model is Initialized with population size by reach for October 2011 from Dudley et al. (2012)	Probability of quasi-extinction for different correlates; ages 0-3	Elasticity analysis indicates long-term dynamics of RGSM populations is strongly tied to reproductive output (fecundity) of Age 0 fish, i.e., those that survive to their first spawning season. Both egg production and first-year survival of newly-hatched fish are critical elements of this fecundity parameter
3. U.S. Fish and Wildlife Service (2016)	Determine (or affirm) relationships between indices of population abundance estimates and occupancy distribution indices (Dudley et al. 2016) with river discharge and levels or areas of water inundation and associated floodplain	Average top width of MRG (Angostura Dam to RM 60 during low flow (July through October) for Very Wet, Average, Very Dry (Bui 2016)	(1) Hydrobiological analyses based on linear and polynomial relationships (scatterplots) between RGSM CPUE and historical river flows; (2) Number of individuals for genetic and population viability derived from MVP and buffered MVP (U.S. Fish and Wildlife Service 2002)	(1) Genetic effective size (Ne) used to compute MVP as minimum size for genetic viability; and (2) buffered MVP as minimum size for population viability	(1) MVP = 16,667 / 49,202.4 x 100m^2) = 0.3 fish per 100 m^2 (lowest density to protect against genetic inbreeding); (2) Average Year buffered MVP = 32,001/ 49,202,205 m^2 = 0.7 fish per 100 m^2. (~ 1.0) for self-sustaining population	MVP (0.3) and Buffered MVP (1.0) used as criteria for Incidental Take Statement of 2016 BiOp
4. Budy and Walsworth (2019)	Review HBO analyses and associated spreadsheet models (USFWS 2016) to provide recommendations for refining the analyses and identifying data gaps	N/A	PCA with 13 variables; PC1 used as “Habitat Quality”	13 flow variables	Analyses ongoing	Analyses ongoing

Summary of Key Documents Principal Variables:

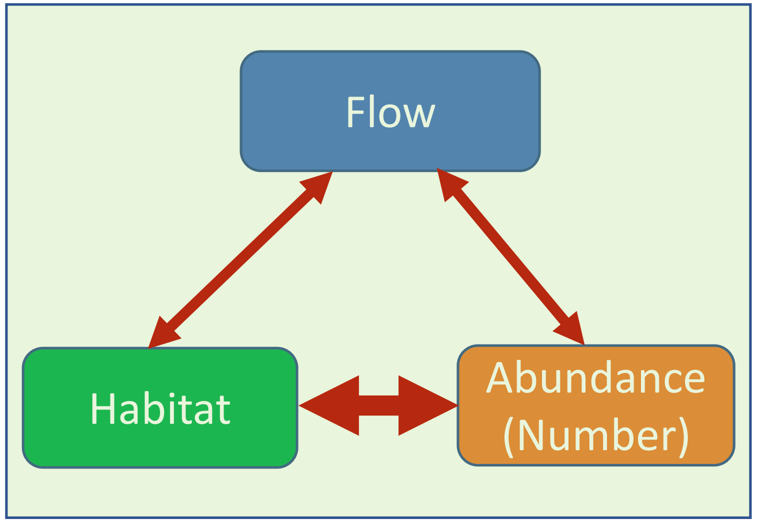


Strong Relationship: Flow to Habitat



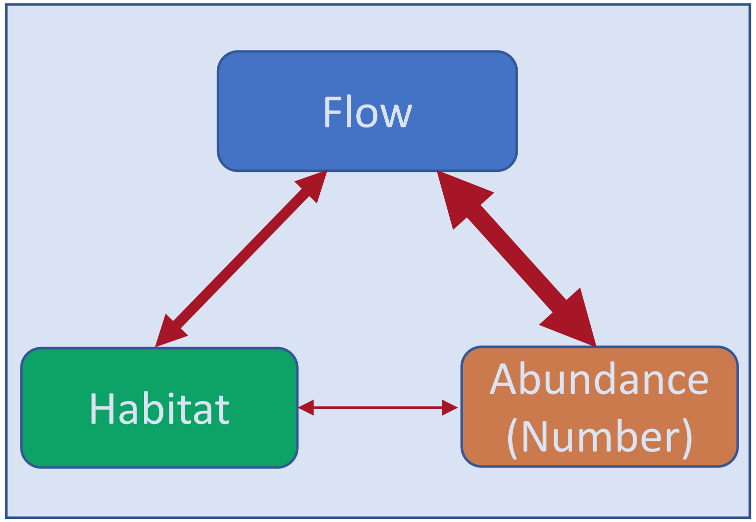
- Remshardt and Tashjian (2003)
- Bovee et al. (2008)
- Tetra Tech (2014)
- Braun et al. (2015)
- Harris et al. (2018)
- Yang et al. (2018)

Strong Relationship: Habitat to Abundance



- Dudley et al. (2011, 2012)
- Miller (2012)

Strong Relationship: Flow to Abundance

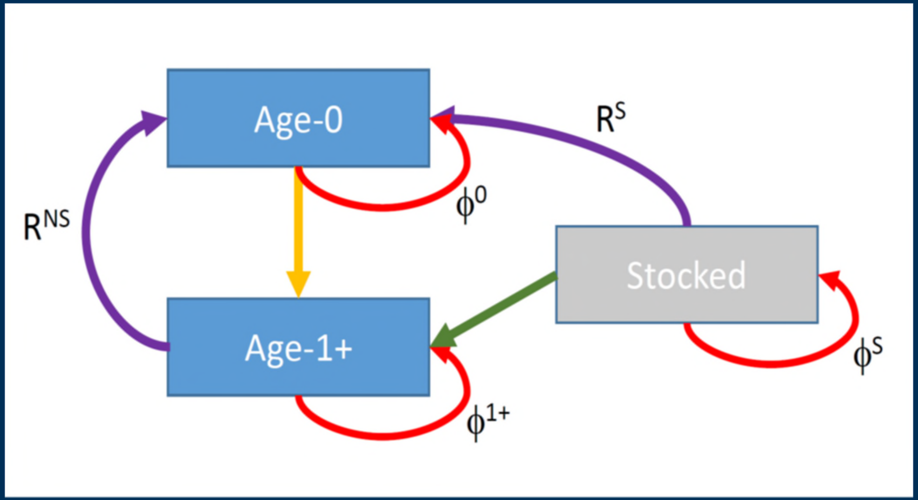


- USFWS (2016)
- Budy and Walsworth (2019)

Steps towards an integrated population modelling of Rio Grande Silvery Minnow

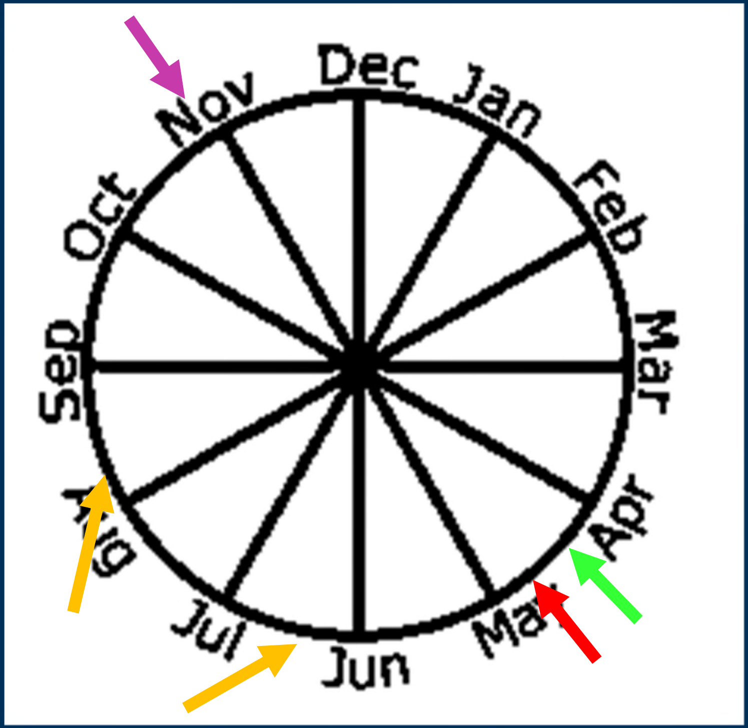
Charles B. Yackulic, *U.S. Geological Survey*

email: cyackulic@usgs.gov



U.S. Department of the Interior
U.S. Geological Survey

Timing of life history and other key events



Spring runoff, floodplain inundation

Spawning

Peak irrigation, drying, salvage.

Augmentation

USGS

Questions/assumptions

- Fecundity in wild?
- cpe to N?
- what role for variation in survival? (especially drying or increased water temperature)
- fate of augmented and salvaged fish?

USGS

Spatial questions

- How much do fish move? (to what degree are diversions barriers?)
- How much do stocked fish move? (difficult to interpret stocked fish data without this info)
- How much of reproduction is local vs. from upstream?

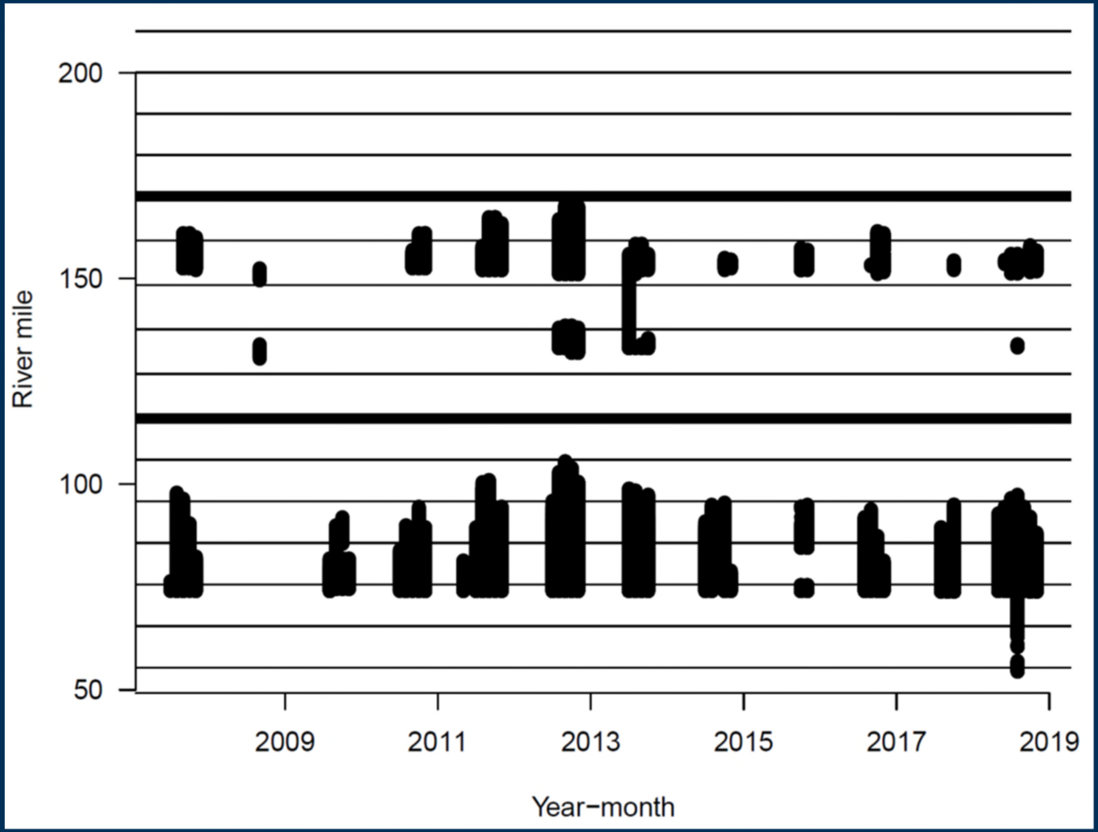
USGS

Data

- Abundance estimates from 4 years.
- Pop. monitoring data from 1993-2018
- Some habitat data
- Discharge
- Augmented (hatchery reared) & marked fish

Other data

- Salvage
- Repeat surveys
- Drying data



USGS

Catch per area seined

Pro's

- Great time series (27 years)
- Good temporal coverage within years (6+ months in most years)
- Decent spatial coverage
- Reasonably standardized

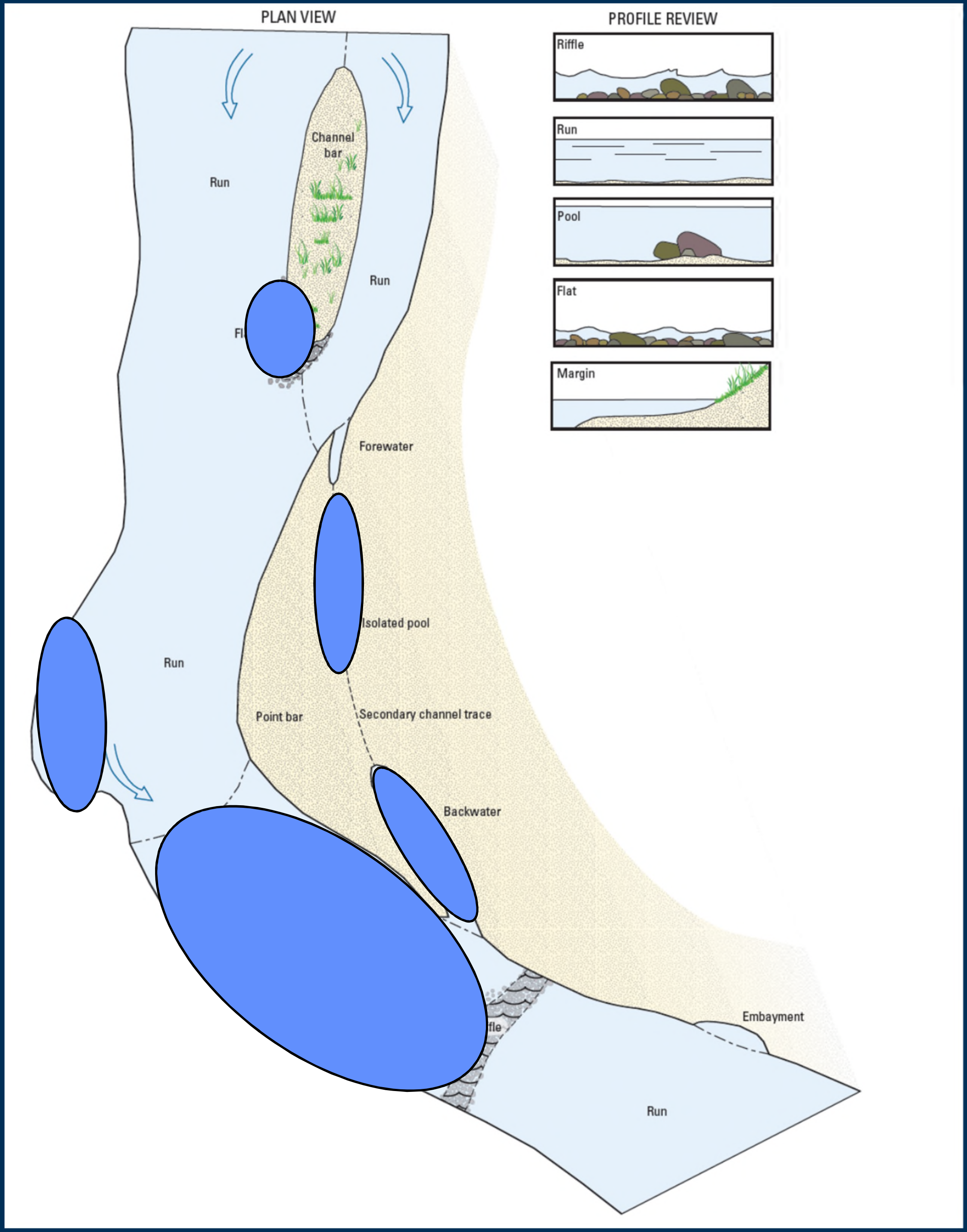
Con's

- Meso-habitat variability
- Unknown total area
- No estimate of sampling uncertainty
  - Relative abundance
  - Density dependence
- Some concerns about catchability of age 1+ fish

USGS

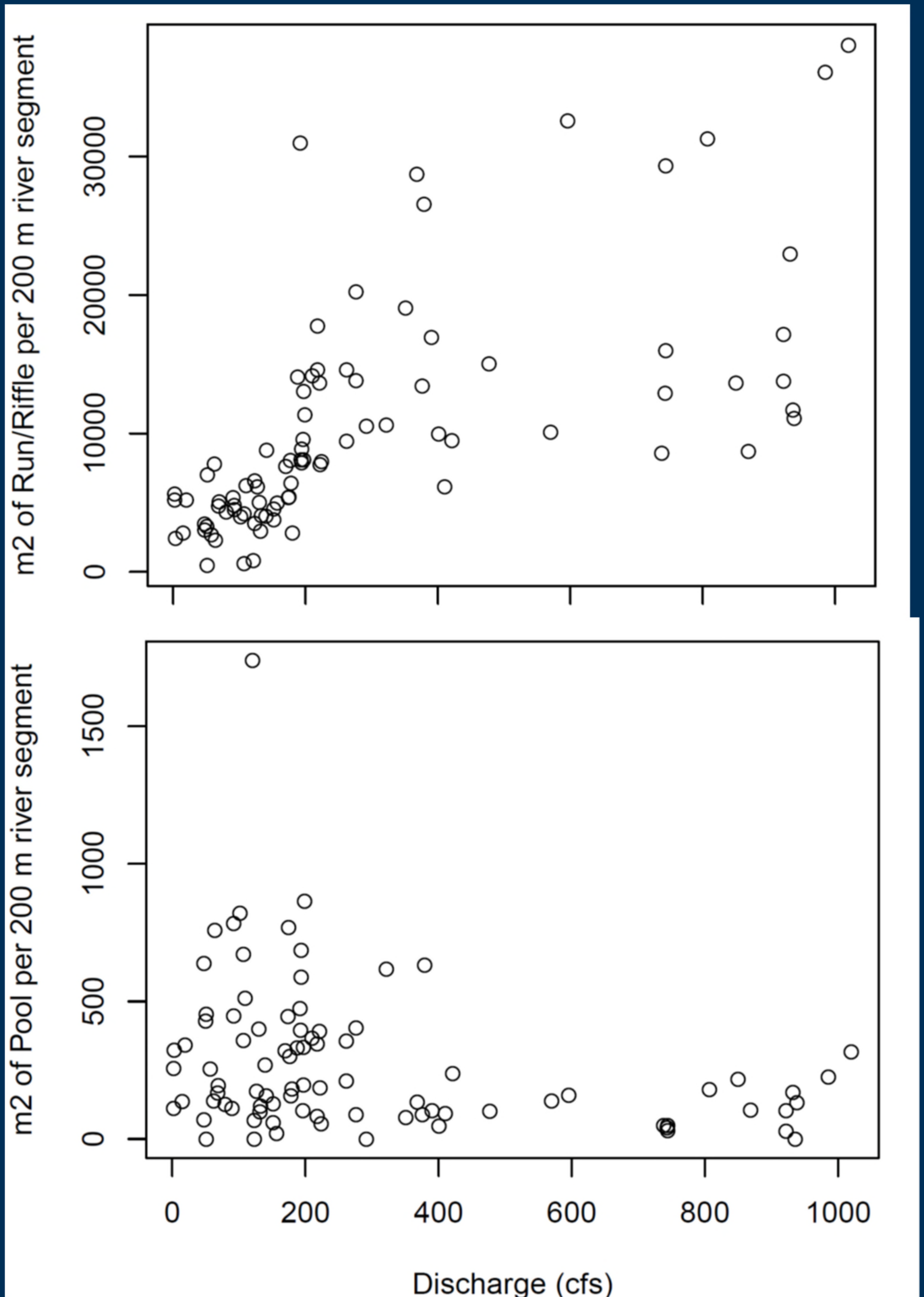
Mesohabitat

- Pool
  - ~4x catch rate of age-0
  - ~3x catch rate of age-1
  - Declining with season for both
- ~25% of samples taken in pool type habitats



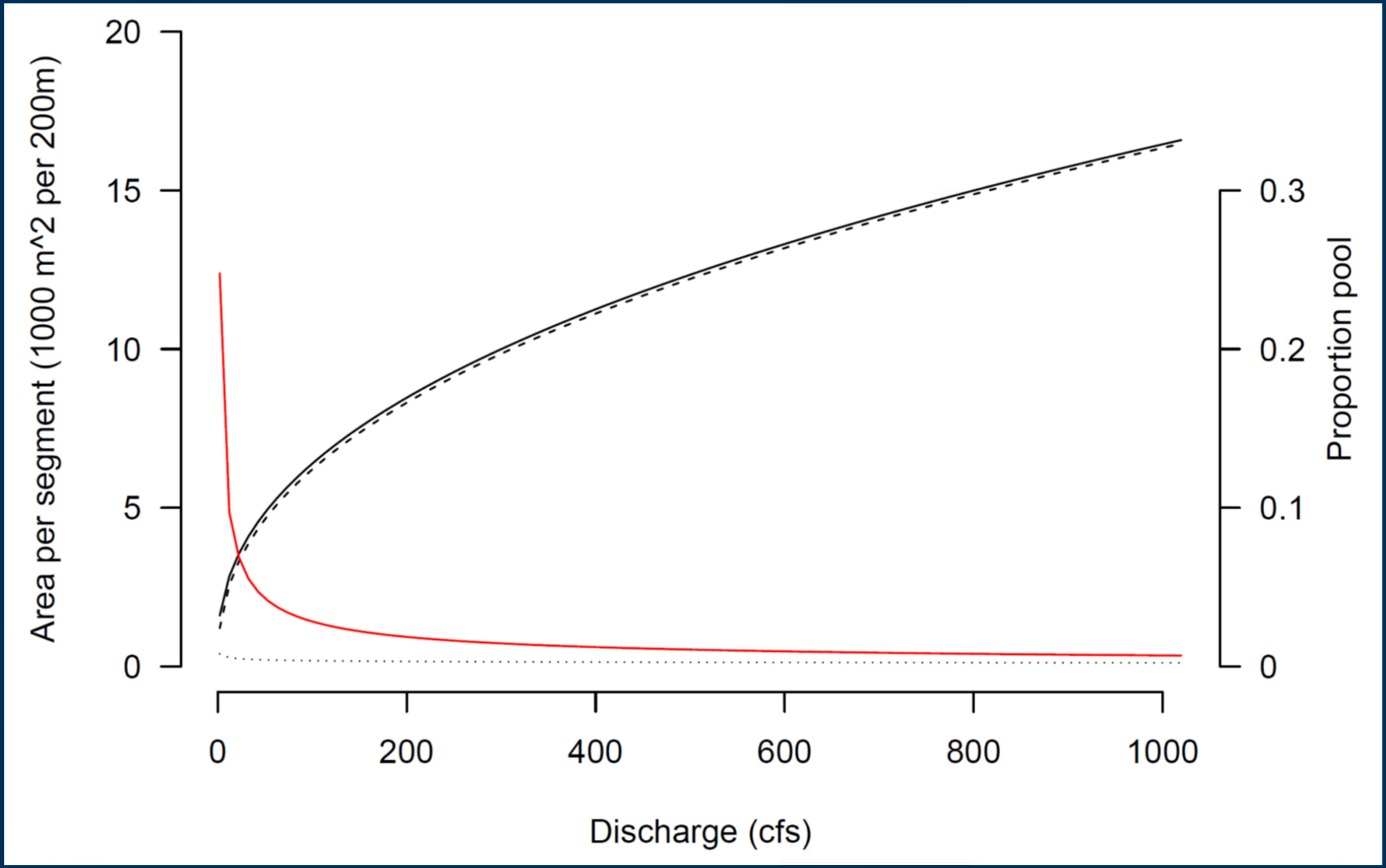
Strata area

- For a stratified random design need to know strata area.



USGS

Strata area



20
15
10
5
0
Area per segment (1000 m^2 per 200m)
0.3
0.2
0.1
0
Proportion pool
0
200
400
600
800
1000
Discharge (cfs)

Some relatively straightforward analyses

- Cpe to N

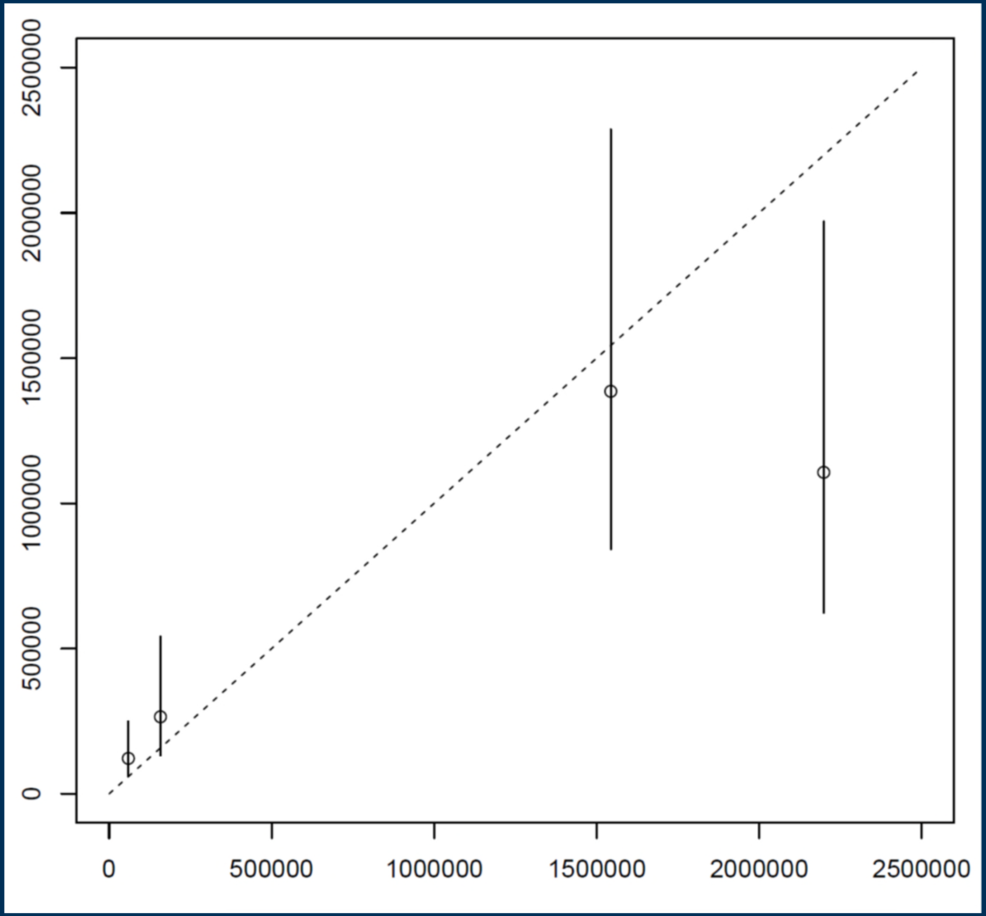
- Fecundity

- Sampling uncertainty

USGS

Cpe to N

- $n = N / 1170$
- $n = n_p + n_r$
- $n_p = A_p d_p$
- $n_r = A_r d_r$
- $pd_p = \frac{c_p}{e_p}$
- $pd_r = \frac{c_r}{e_r}$
- $n = \frac{A_p \frac{c_p}{e_p} + A_r \frac{c_r}{e_r}}{p}$



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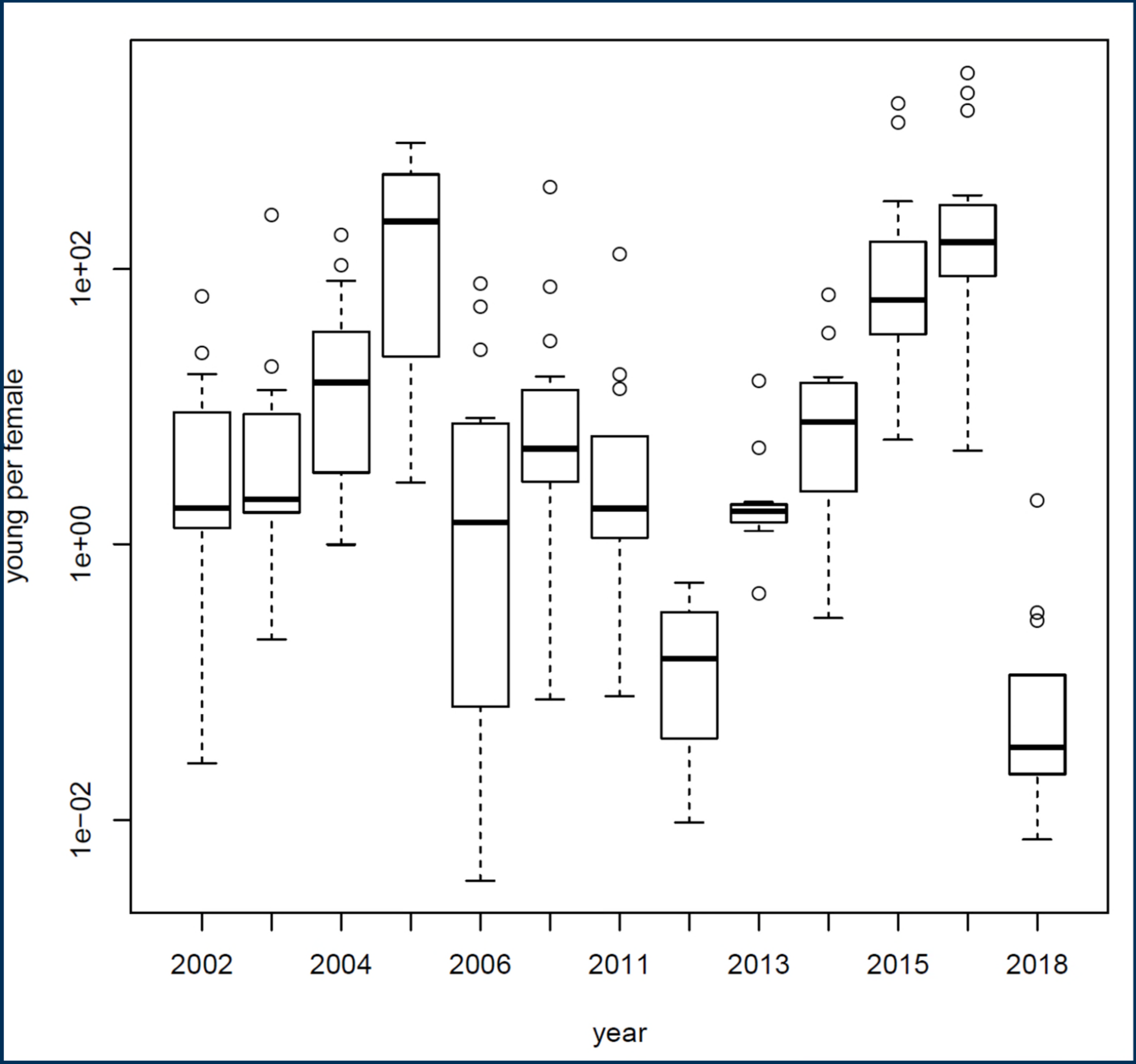
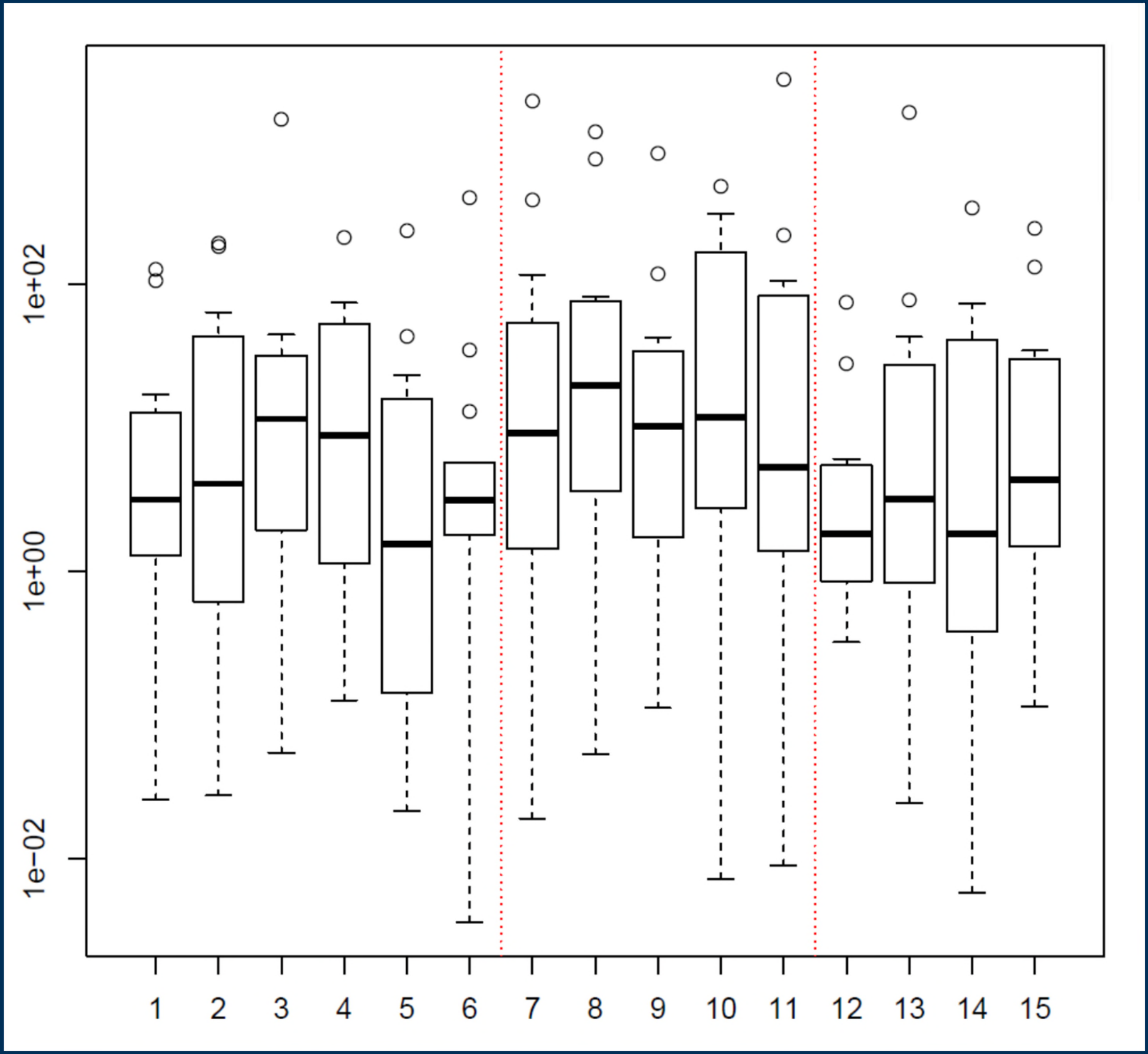


young per female
1e+02
1e+00
1e−02
2002
2004
2006
2011
2013
2015
2018
year

USGS



1e+02
1e+00
1e−02
1
2
3
4
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6
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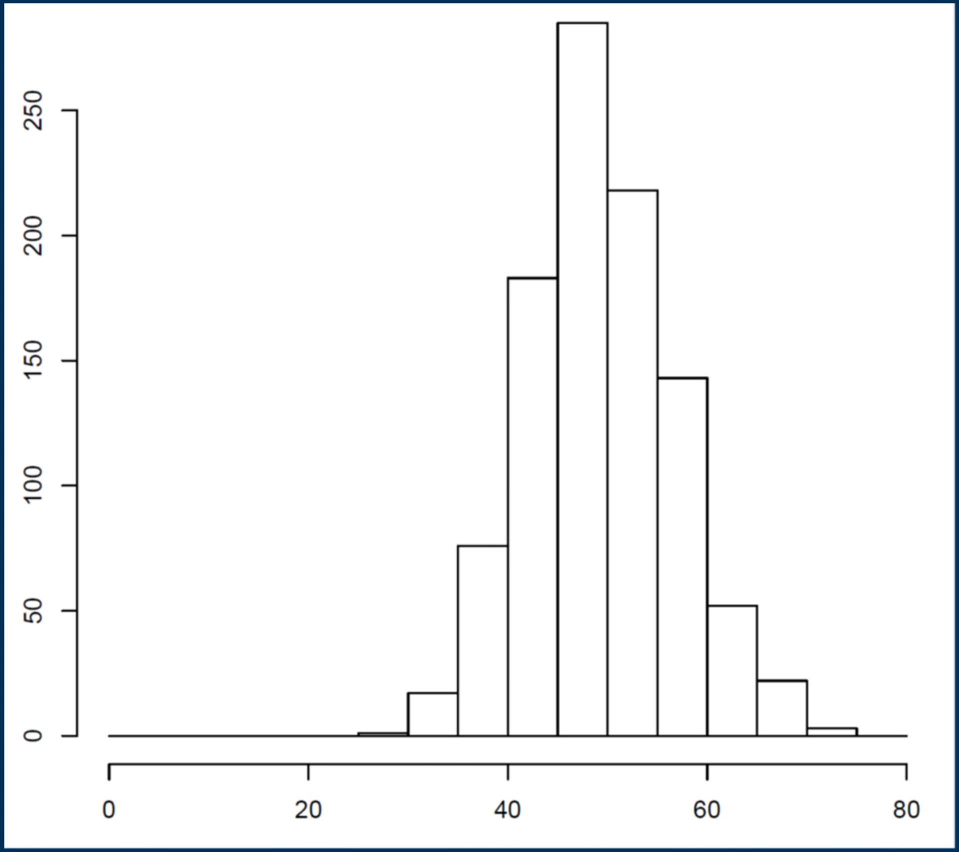
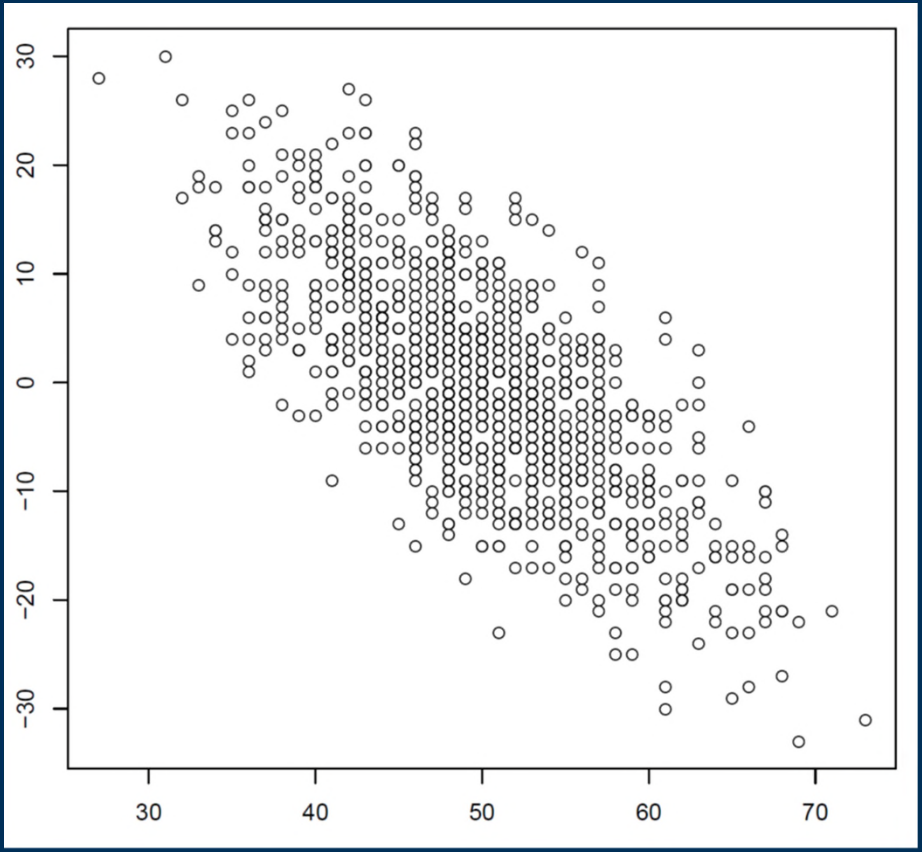
15

Sampling uncertainty and density dependence





USGS

Questions/assumptions

- Fecundity in wild?
- cpe to N?
- what role for variation in survival? (especially drying or increased water temperature)
- fate of augmented and salvaged fish?

USGS

Spatial questions

- How much do fish move? (to what degree are diversions barriers?)
- How much do stocked fish move? (difficult to interpret stocked fish data without this info)
- How much of reproduction is local vs. from upstream?

Rio Grande Silvery Minnow Model Survey

The Middle Rio Grande Endangered Species Collaborative Program's Population Monitoring Workgroup (PMW) began developing an integrated stock assessment model for the Rio Grande silvery minnow (RGSM) in 2018. This model will integrate environmental and species-specific information and data to assess the status of the RGSM population in the Middle Rio Grande, and ultimately make predictions about how the population may respond to current and future management options. Species-specific information will include RGSM vital rate information, such as growth, survival, and reproductive capabilities of RGSM at various ages.

To complete this model, the Albuquerque Bernalillo County Water Utility Authority and New Mexico Interstate Stream Commission contracted Dr. Charles Yackulic of the Southwest Biological Science Center of the U.S. Geological Survey through the 2019 and 2020 fiscal years. The PMW has been and will continue to work closely with Dr. Yackulic in the development and evaluation of the integrated stock assessment model. To assist in model development, PMW is soliciting feedback from stakeholders regarding the types of management questions that you would like us to consider, such as:

1. What does a self-sustaining population of silvery minnows look like in the Middle Rio Grande according to this population model? How many individuals, sexes, and ages does the model predict are most likely present in the different reaches by season?
2. How does this modeled population respond to different types of water management actions? What is the expected measurable effect of intermittency, river drying, spring flow augmentation, or habitat restoration efforts on the modeled population?

Please provide us with your feedback in the space provided below. All input will be consolidated for consideration by the PMW and Dr. Yackulic during model development and testing. Additionally, we anticipate a future interactive modeling workshop with interested parties and Dr. Yackulic. Please help us schedule this workshop by selecting which time frames work best for you (final question).

1. Email Address

2. Please detail the management questions you would like to be considered:

3. When should we consider holding a modeling workshop? Please select all time frames that work for you.

______Between January 13th and January 24th

______Between January 27th and February 7th

______Between February 10th and February 21st

Rio Grande Silvery Minnow Sampling Methods

Population Monitoring (PM) & Population Estimation (PE)

Robert K. Dudley[1,2], Steven P. Platania[1,2], and Gary C. White[1,3]

[1] American Southwest Ichthyological Researchers (ASIR); 800 Encino Place NE, Albuquerque, NM, 87102
[2] Museum of Southwestern Biology (Fishes), UNM; MSC03-2020, Albuquerque, NM, 87131
[3] Dept. of Fish, Wildlife, and Conservation Biology, CSU; 10 Wagar, Fort Collins, CO, 80523

Native Distribution
(*Hybognathus amarus*)

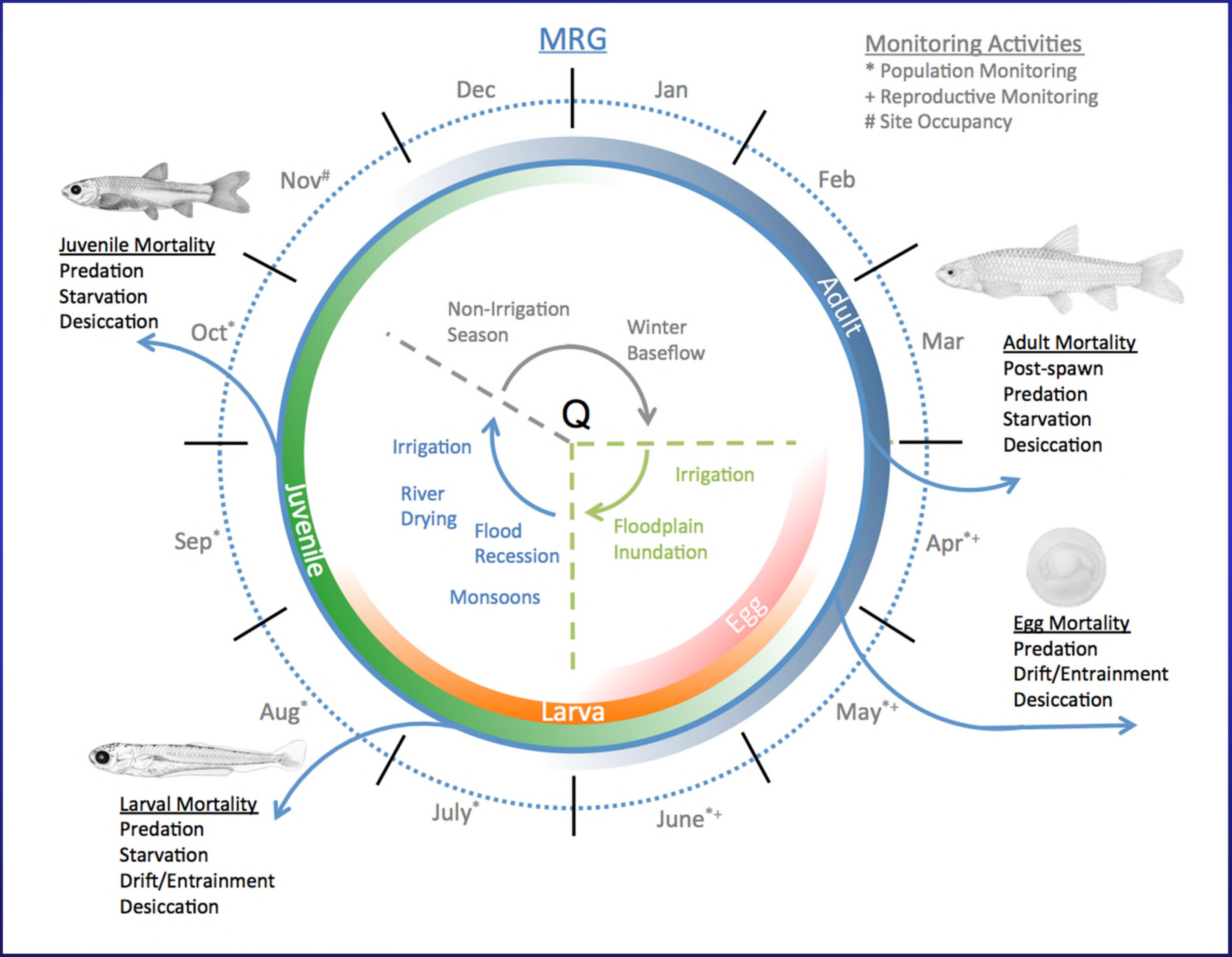
Current

Historical

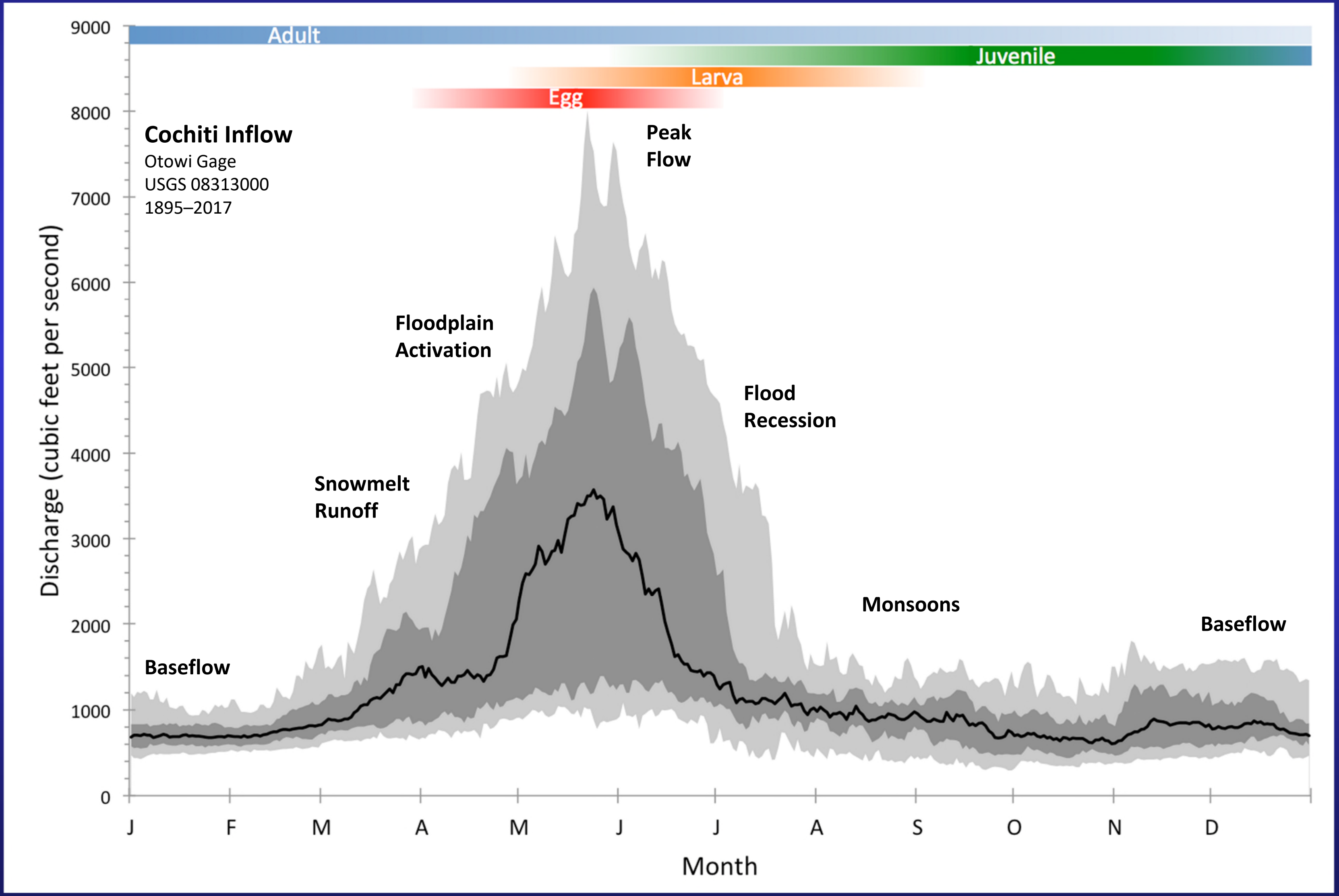
Experimental

Rio Grande PS Reproductive Guild:
Rio Grande Silvery Minnow *Hybognathus amarus*
Speckled Chub *Macrhybopsis aestivalis*
Rio Grande Shiner *Notropis jemezanus*
Phantom Shiner *Notropis orca*
Rio Grande Bluntnose Shiner *N. simus simus*

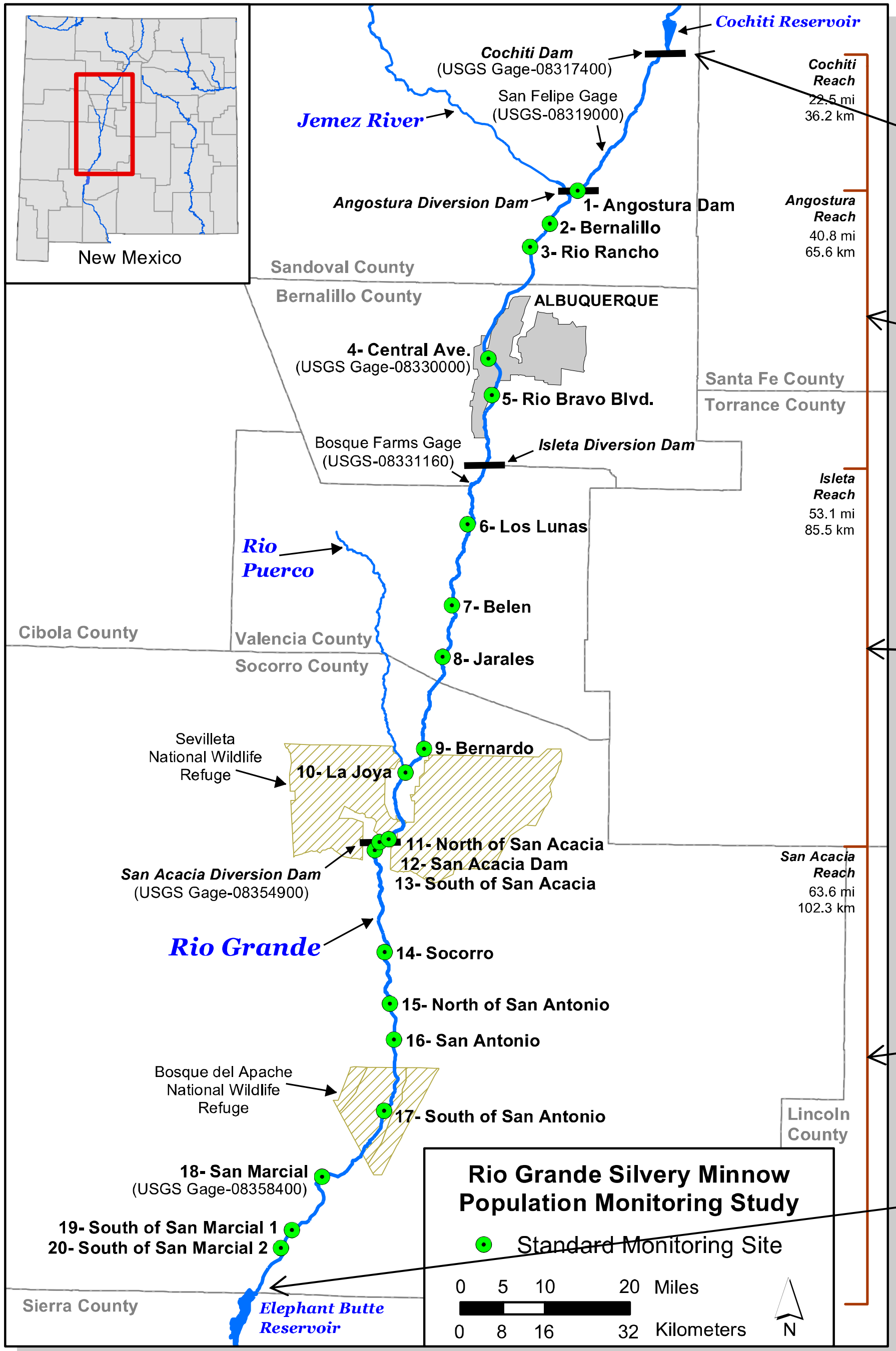
Life History of Rio Grande Silvery Minnow



Life History of Rio Grande Silvery Minnow



Study Area



Cochiti Dam

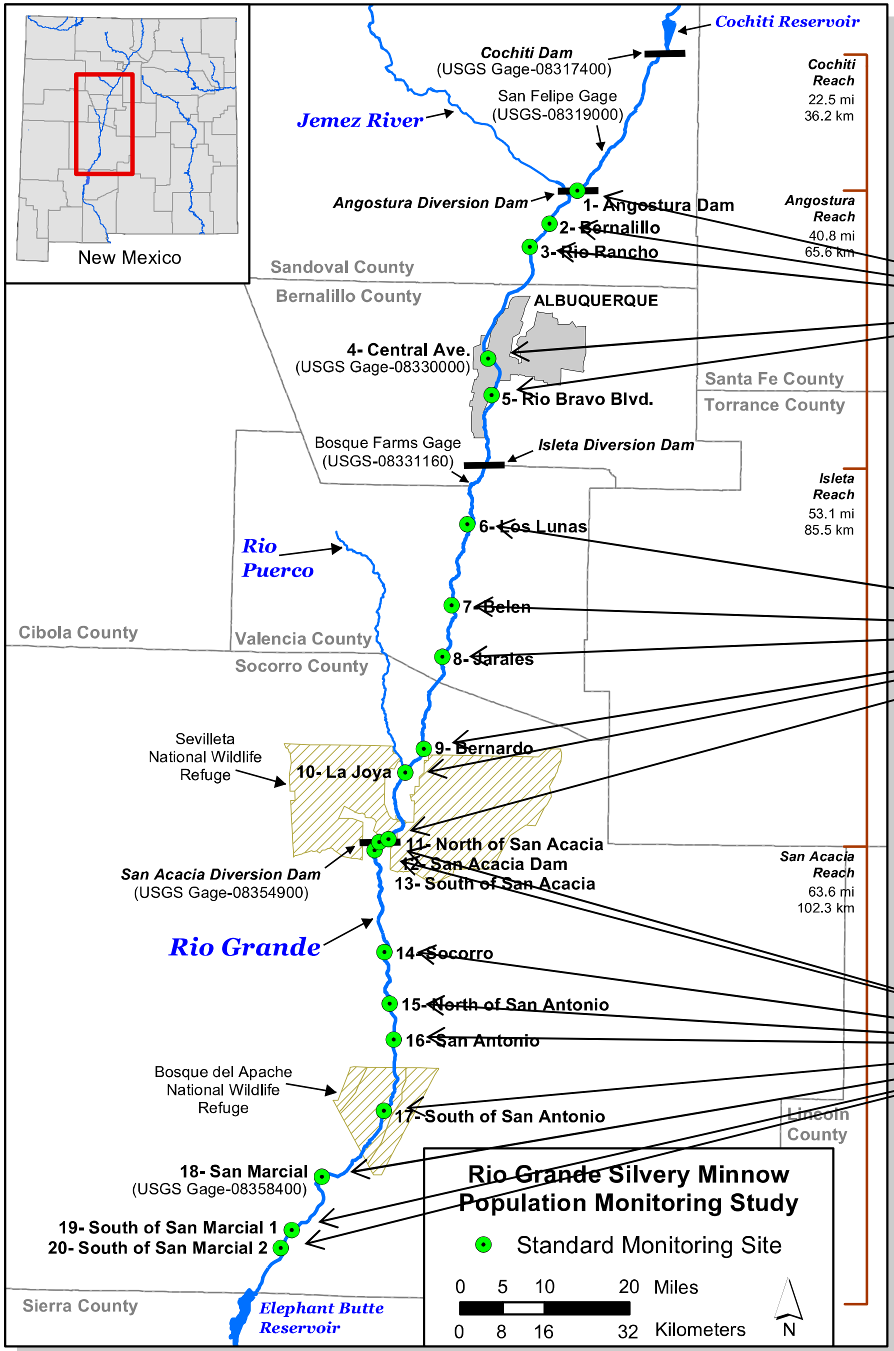
Angostura Reach

Isleta Reach

San Acacia Reach

Elephant Butte Reservoir

PM Sampling Sites

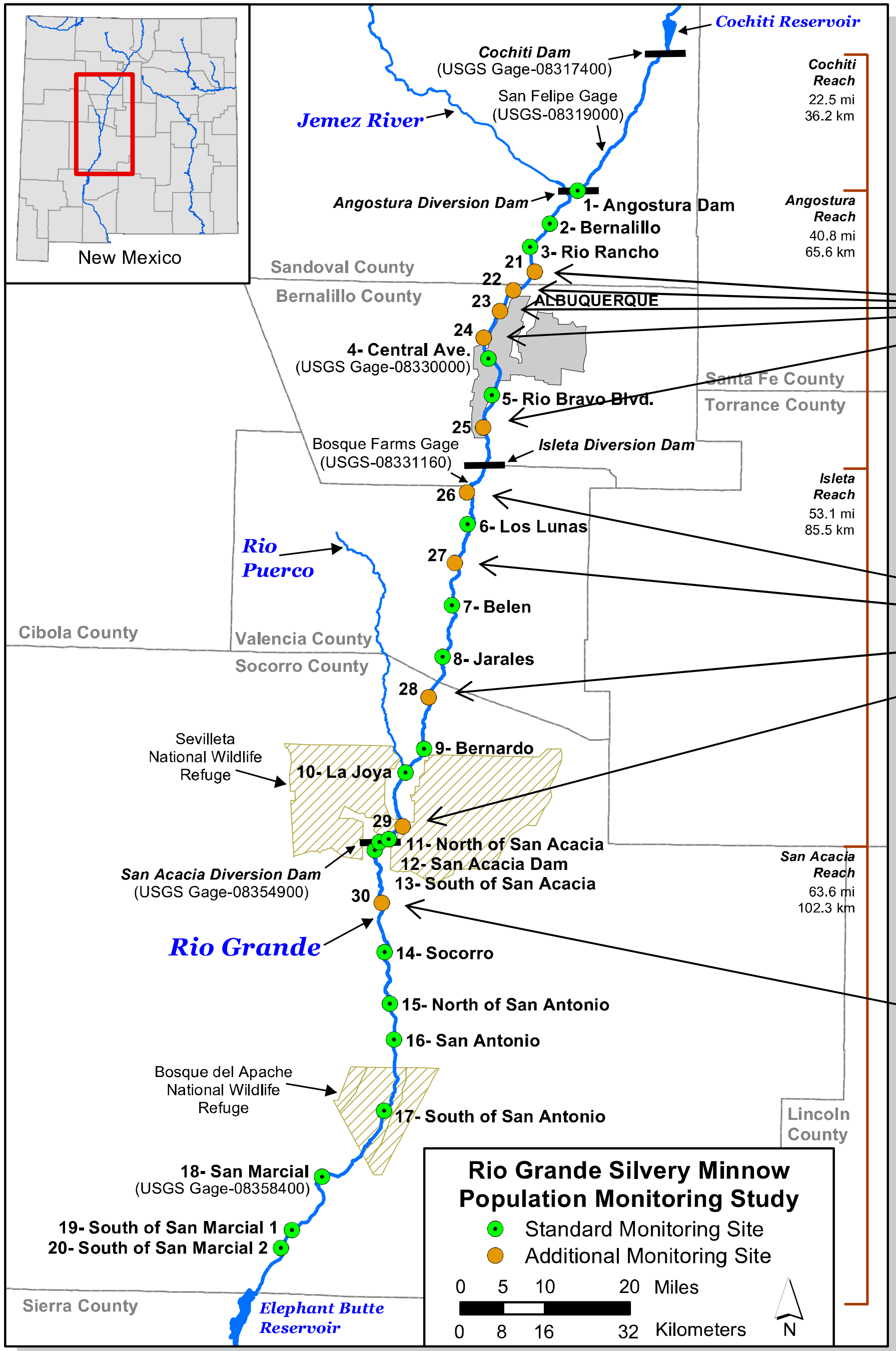


Angostura Reach sites (5)

Isleta Reach sites (6)

San Acacia Reach sites (9)

PM Additional Sites

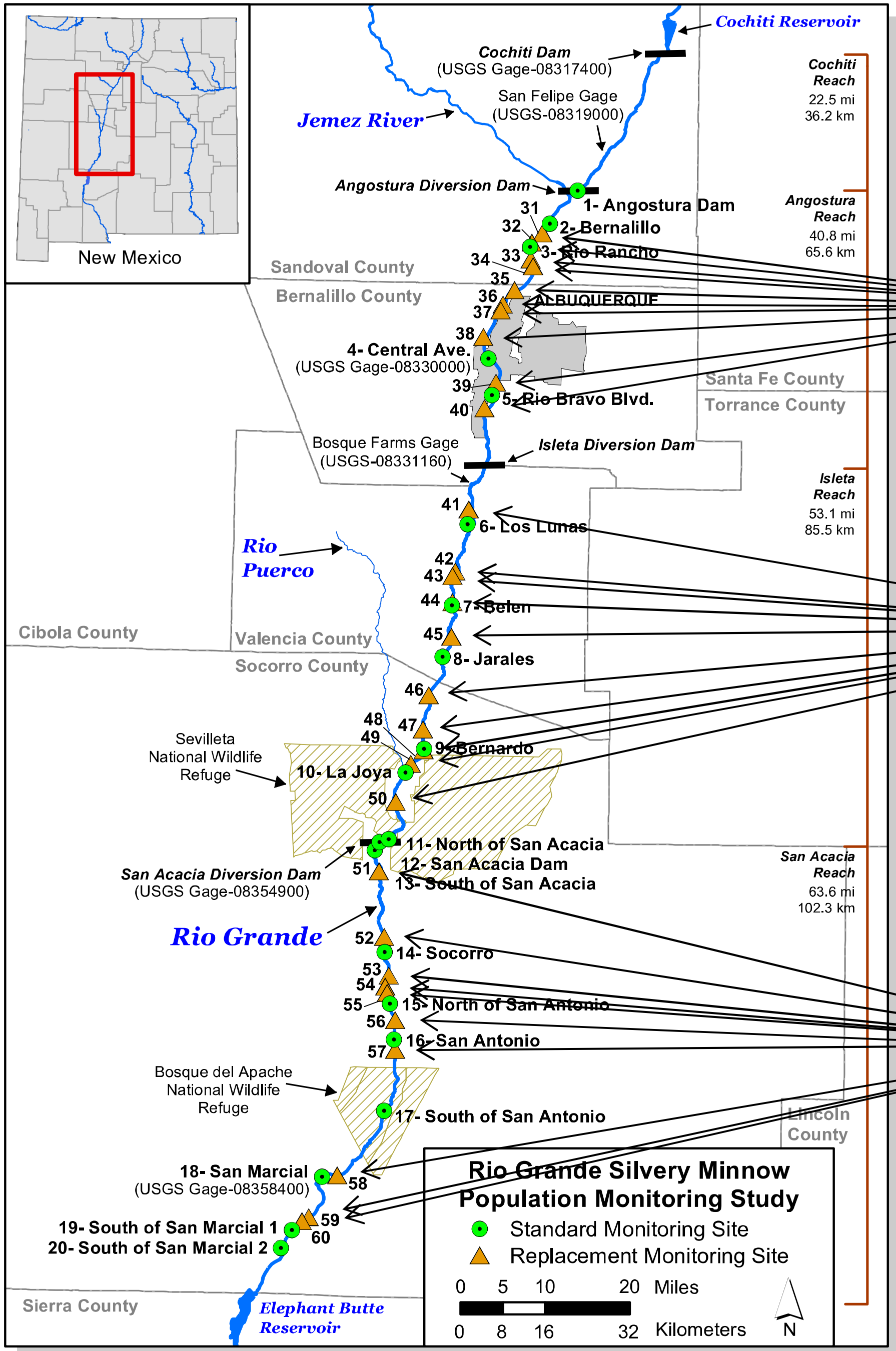


Angostura Reach sites (5)

Isleta Reach sites (4)

San Acacia Reach sites (1)

PM Replacement Sites

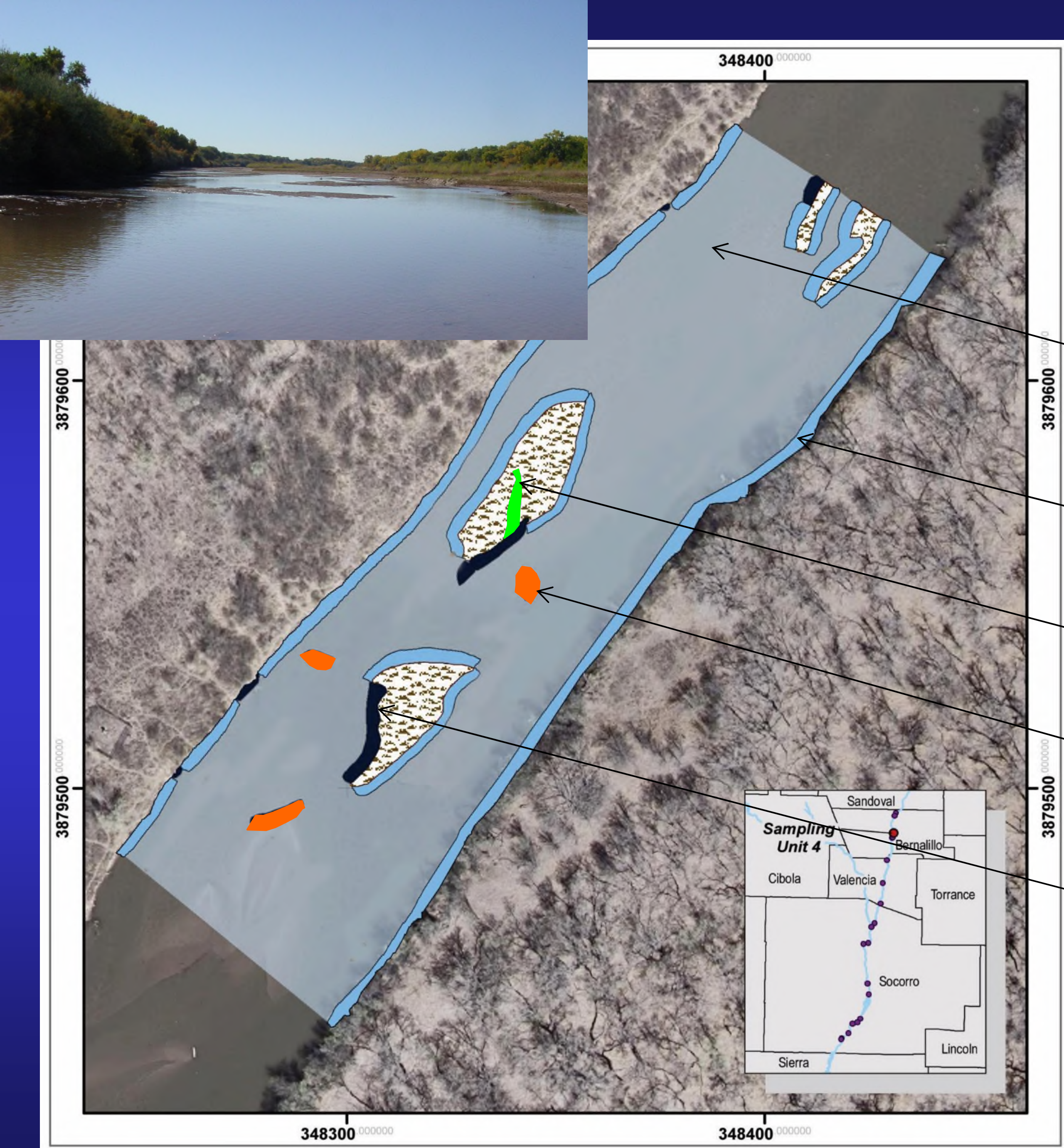


Angostura Reach sites (10)

Isleta Reach sites (10)

San Acacia Reach sites (10)

Mesohabitats



Runs (RU)

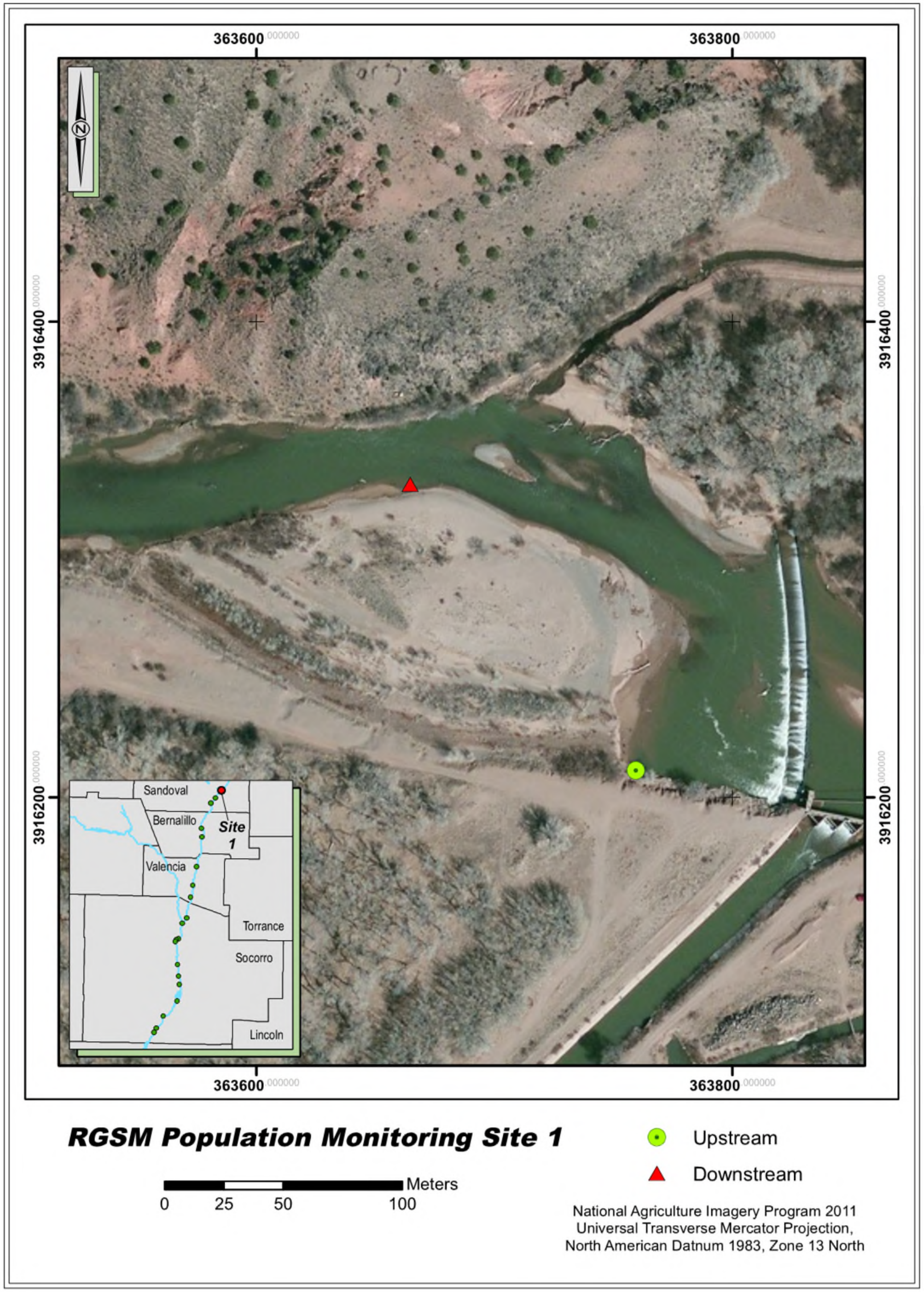
Shoreline runs (SHRU)

Backwaters (BW)

Pools (PO)

Shoreline pools (SHPO)





PM Sampling Methods

Seine hauls by mesohabitat:
- (BW/PO = 2, RU/SHPO = 4)
- (SHRU = 6–14)

Adult fish seining (18):
- (3.1 m x 1.8 m; small mesh)

Larval fish seining (2):
- (1.0 m x 1.0 m; fine mesh)

Twenty seine hauls per site:
- Mesohabitats standardized
- Similar sampling across flows
- Area sampled (ca. 500 m^2)

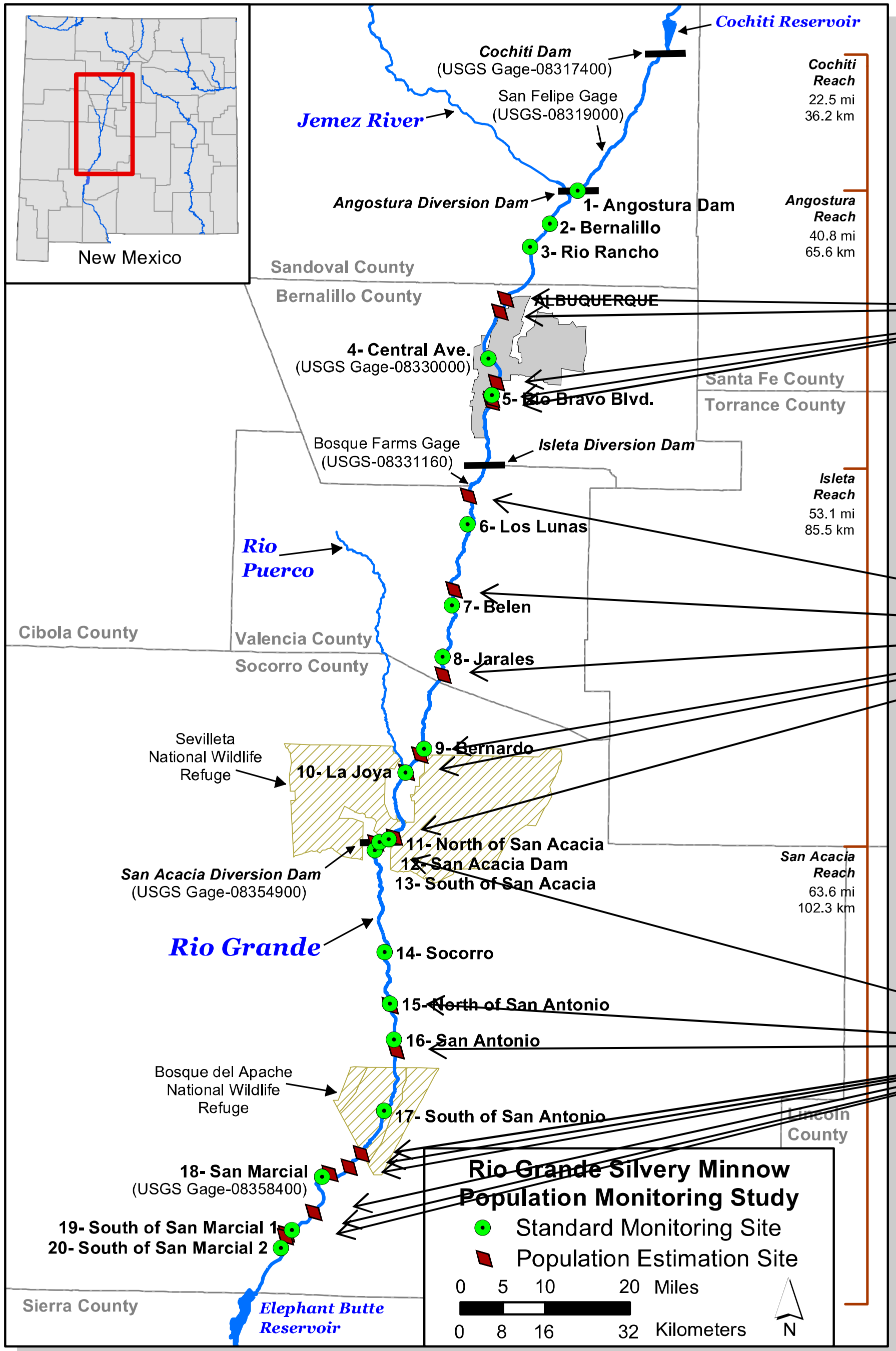
Evolution of PM Project Design

- The decline of RGSM during a prolonged drought (2000–2003), and formation of the MRGESCP, prompted notably increased sampling efforts (i.e., from quarterly to monthly).
- An external review, led by nationally-recognized experts, resulted in a workshop and a report (2004–2005).
- Most of the sampling recommendations and *research studies*, suggested by the experts, were initiated in 2006.
- The Population Monitoring Group (MRGESCP) produced a consensus report in 2006 on the desired protocols and objectives for this study.
- The most recent external review, led by nationally-recognized experts, resulted in a workshop and a report (2015–2016), along with several recommendations for increased sampling efforts.

Evolution of PE Project Design

- An external review, led by nationally-recognized experts, resulted in a workshop and a report (2004–2005).
- The experts suggested that additional research was needed to evaluate the feasibility of converting existing density data into an estimate of population size.
- Open (one-pass using seines) vs. closed (multiple-pass removals using seines or electrofishing) sampling techniques were extensively evaluated through a series of field experiments (2006–2007).
- Based on the revised/final field sampling methods (i.e., multiple-pass removals using electrofishing), the overall and reach-specific population size of RGSM during October was estimated from 2008 to 2011.

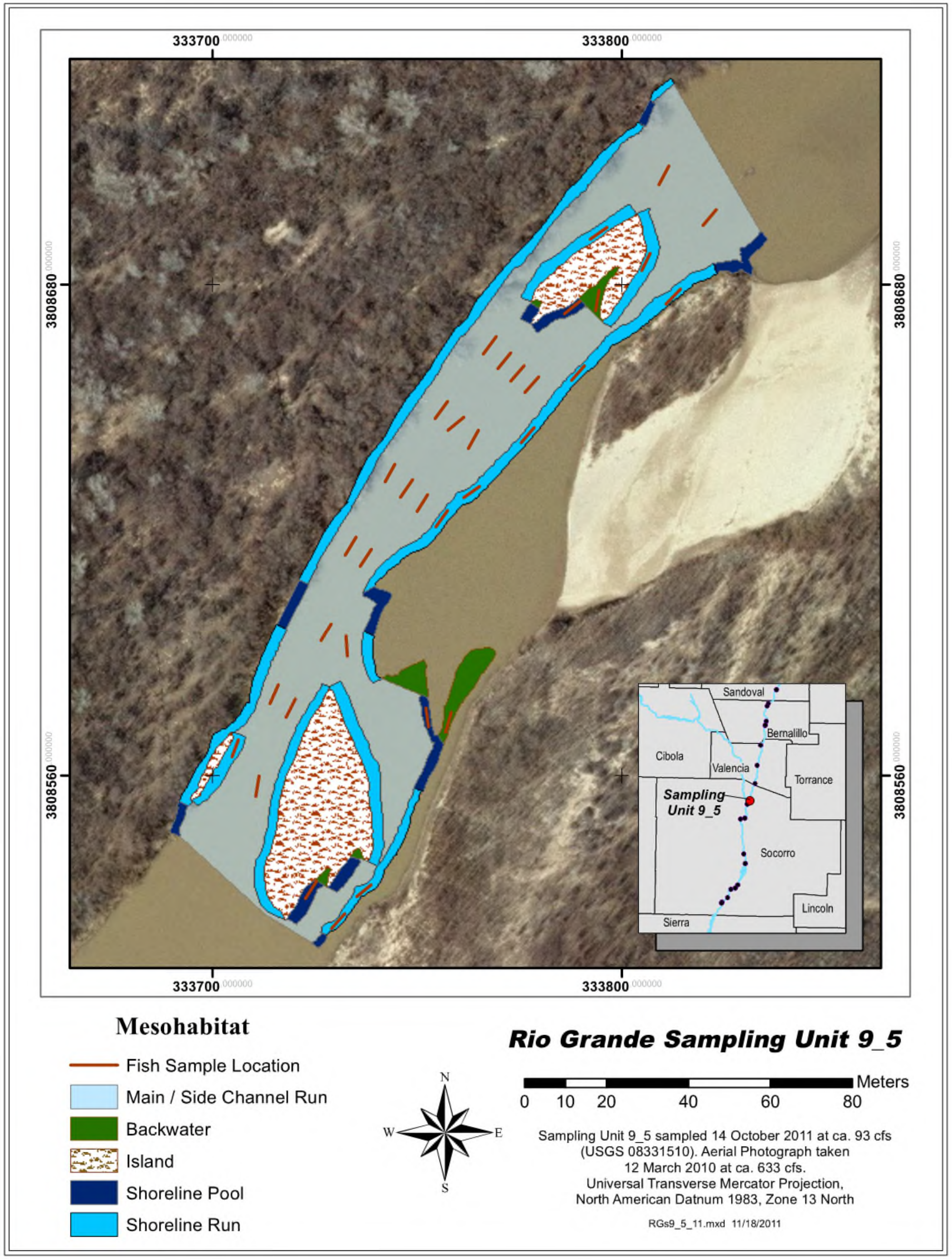
PE Sampling Sites



Angostura Reach sites (5)

Isleta Reach sites (6)

San Acacia Reach sites (9)



PE Sampling Methods

Mapping of all mesohabitats:

- Boundaries of all mesohabitats were marked with flags/posts
- Mapped with a GPS Pathfinder Receiver and a Ranger Data Collector

Removals by mesohabitat:

- Randomized sampling locations for both run and non-run habitats
- Removal-sampling was conducted in portable enclosures using electrofishing

About 30–50 samples per site:

- Mesohabitats standardized
- Similar sampling across flows
- Area sampled (ca. 500 m^2)

Open vs. Closed Sampling in Run Mesohabitats

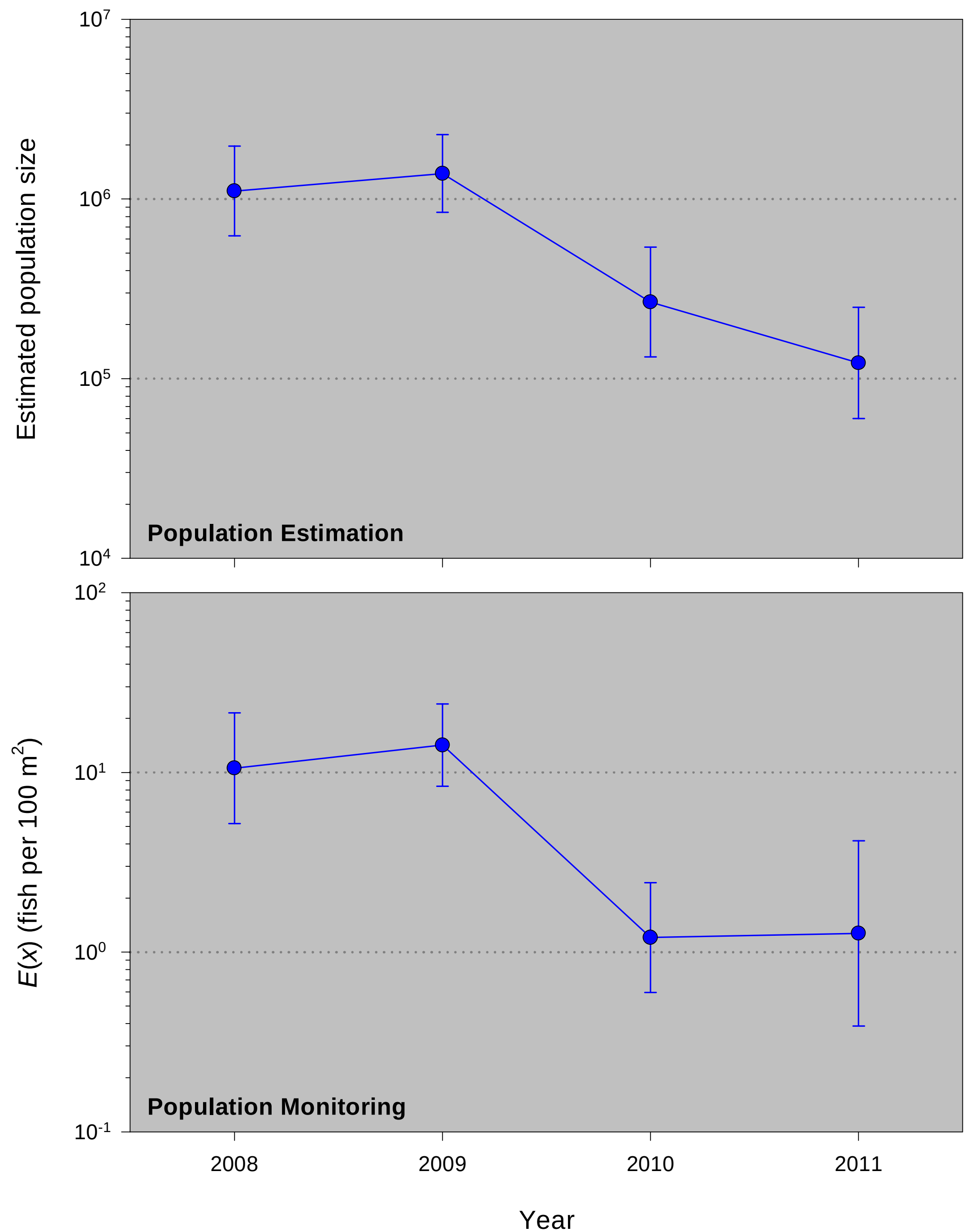
Open vs. Closed Sampling in Non-Run Mesohabitats

Population Trends
(Estimation vs. Monitoring)

- Similarities: Twenty sites, mesohabitats standardized, similar sampling across flows, area sampled (ca. 500 m^2)

- Differences: Random sites and mesohabitats, mapping of mesohabitats and samples, electrofishing removal-sampling in enclosures

- Despite notable differences in methodology and required effort, both studies indicated very similar trends over time.



Comparing Different Studies

Study strengths	Lower abundance	Higher abundance	Overall
Population monitoring	Early indication of decreased occurrence and abundance	Early indication of increased occurrence and abundance	Seasonal & annual trends in occurrence and abundance
Site occupancy	Robust measure of decreased occurrence (extinction)	Robust measure of increased occurrence (colonization)	Robust estimate of annual occurrence
Population estimation	Robust measure of decreased abundance	Robust measure of increased abundance	Robust estimate of annual abundance

Summary

1. The population monitoring and population estimation studies employed notably different sampling methodologies and required substantially different amounts of effort.

2. Despite these differences, both studies resulted in very similar estimates of Rio Grande Silvery Minnow population trends over time.

3. The population monitoring and population estimation studies each have their own unique set of strengths/weaknesses and costs/benefits.

4. More accurately determining changes in the conservation status of Rio Grande Silvery Minnow, using a variety of monitoring techniques, should aid in both the long-term management and recovery of this imperiled species.

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- **Report Review:** Jennifer Bachus, Eric Gonzales, and James Wilber (USBR)

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