Summary of Findings by the External Expert Panelists: Rio Grande Silvery Minnow Population Monitoring Workshop

Isleta Casino and Resort, 8-10 December 2015

Wayne Hubert, Facilitator and Expert Panelist

Mary Fabrizio and **Robert Hughes**, Expert Panelists

Matt Cusack, Administrative Support and Project Manager

Prepared by the expert panelists

On behalf of the

U.S. Bureau of Reclamation

Submitted by:

ATKINS

FINAL REPORT

REVISED May 17, 2016

Contents

Executive Summary 1
1.0 Introduction 3
1.1 Workshop Logistics 4
2.0 Population Monitoring Workgroup Question 1 6
2.1 Definition of catch per unit effort (CPUE) 6
2.2 Definition of the MRG fish population in the Monitoring Program 7
2.3 Sampling gears used in the Monitoring Program 7
2.4 Standardization of catch rates 7
2.5 Sampling effort in the presence of dry sites 8
2.6 Age composition of the catch 8
2.7 Multiple sampling gears and CPUE 9
2.8 Factors affecting the catchability coefficient of sampling gears 9
2.9 The assumption that CPUE is a function of abundance (i.e., $C/f = qN$) 10
2.10 Alternative sampling gears 11
2.11 Appropriate use of CPUE indices as recovery standards 11
3.0 Population Monitoring Workgroup Question 2 11
3.1. Random versus non-random or stratified site selection 12
3.2 Fixed-site versus variable-site sampling 12
3.3 Sample size 13
3.4 Sub-group inclusion 15
3.5 Site-scale sampling protocol 15
4.0 Population Monitoring Workgroup Question 3 16
4.1 Mixture models and estimation of the CPUE index 16
4.2 Flexibility of mixture models 18
4.3 Mixture models and the effect of covariates on CPUE estimates 18
4.4 Classification of mesohabitat types 19
4.5 Key drivers of mesohabitat variability 19
4.6 Relationship of hydrological variables to mean CPUE 20
4.7 Detection of RGSM in seines 20
4.8 Use of the lognormal distribution to describe non-zero catches 21
4.9 Mixture model assumptions 21

4.10 Estimation of mean site-specific CPUE 22
4.11 Zero catches 23
4.12 Alternatives to mixture models 23
4.13. Alternatives for exploring relationships between CPUE and covariates 23
4.14. Defining spatial scales relevant to RGSM 24
5.0 Population Monitoring Workgroup Question 4 24
5.1. Sampling design 25
5.2. Population biology 26
5.3. Improved collaboration among Collaborative Program elements 27
6.0 Recommendations 28
6.1 CPUE computation 28
6.2 Survey design 29
6.3 Future research 30
7. Observations beyond the scope of the Population Monitoring Workshop 30
8.0 References 35

List of Appendices

- Appendix A: Agenda
- Appendix B: Ground Rules
- Appendix C: Questions
- Appendix D: List of Provided Reference Materials
- Appendix E: Attendees
- Appendix F: Recorded Notes during the Workshop (Days 1 and 2)
- Appendix G: Recorded Notes during the Workshop (Day 3)

List of Tables and Figures

Table 1. Technical Participants at the Rio Grande Silvery Minnow Population Monitoring Workshop 5

Figure 1. Effects of sample size (number of sites) on the variance of a slope (modified from Larsen et al. 2004) 13
Figure 2. Data appropriate for alternative Poisson models (from Hu et al. 2011) 17

List of Abbreviations and Acronyms

CPUE- Catch Per Unit Effort

IBM- Individual Based Models

Monitoring Program- Rio Grande Silvery Minnow Monitoring Program

MRG- Middle Rio Grande

MWCW- Mean wetted channel width

Planning Workgroup- Population Monitoring Workshop Planning Workgroup

Collaborative Program- Middle Rio Grande Endangered Species Collaborative Program

RIP- Recovery Implementation Program

RGSM- Rio Grande Silvery Minnow

Executive Summary

The Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) is comprised of multiple stakeholders representing diverse interests related to water operations and management within the Middle Rio Grande (MRG), New Mexico. The Collaborative Program works to comply with the Endangered Species Act and support the recovery of the federally listed species that occupy this reach. The Collaborative Program has a special emphasis on the Rio Grande Silvery Minnow (*Hybognathus amarus*; RGSM) and the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) and, simultaneously, to protect existing and future water uses while complying with applicable state and federal laws, rules and regulations. The Collaborative Program is transitioning to become a Recovery Implementation Program (RIP), and will be establishing sufficient progress metrics for the RIP that may include species demographics.

As part of a transition to a RIP, the Collaborative Program is beginning its review of the Monitoring Program, including its indices and methodologies. However, there is disagreement among the parties of the Collaborative Program regarding whether the trends detected by the Monitoring Program fully meet the needs of the Collaborative Program. To address these concerns, the Bureau of Reclamation sponsored a workshop in December 2015 to discuss the current Catch per Unit Effort (CPUE) methodologies and sampling design as the Collaborative Program's next step in further development of the Monitoring Program.

This report is organized to address four primary questions that were provided to the expert panelists in advance of the workshop.

---

(1) Is the CPUE index appropriate for monitoring the Rio Grande Silvery Minnow in the Middle Rio Grande?

(2) Are the monitoring plan and sampling design appropriate for tracking the status and trend of the RGSM in the Middle Rio Grande?

(3) A. Are the statistical analyses used in the Monitoring Program appropriate and in line with data distributions and characteristics?

(3) B. Are there additional analytical techniques that could be used that would improve the use of CPUE?

(4) What revision can be made to the sampling design to improve accuracy, precision, and power to detect change in RGSM abundance?

In advance of the workshop, the expert panelists were provided with data sets along with relevant documents and publications. The materials were carefully selected by consensus of the Collaborative Program members. In this report, the panelists address each of the four primary questions of the workshop, and provide additional observations and recommendations related to the topics of CPUE computation, survey design, trend analysis, and future research.

The expert panelists concluded that existing use of CPUE indices provide a reasonable indication of status and trends for monitoring RGSM in the MRG; however, several modifications to the computation of CPUE used in the Monitoring Program would provide more accurate indices of RGSM abundance. The recommendations include: (1) separation of the catch and effort data from the small-mesh seine and the fine-mesh seine into two data sets and computation of separate CPUE indices for each gear type, as well as for specific age classes captured with each gear type; (2) exclusion of older fish from the CPUE index derived from the small-mesh seine because it is primarily an index of the relative abundance of a single cohort of RGSM that is recruited into the gear late in the summer and captured into the summer of the following year; and (3) inclusion of only larval fish in the CPUE index derived with the fine-mesh seine because it is primarily an index of larval fish abundance. These changes in computation of CPUE indices will require modification of recovery standards for RGSM to include specific descriptions of sampling gear, sampling design, sampling techniques, computation of CPUE, data analysis, and size classes used to compute CPUE indices.

The expert panelists concluded that the current monitoring plan and sampling design are appropriate for tracking the status and trends in abundance and occurrence of age-0 RGSM in the MRG, but when fixed sites are found to be dry at the time of sampling events, the sampling design and CPUE indices are compromised. The current fixed-site sampling is not adequate when dry sampling sites occur. An ancillary randomized sampling design is recommended at such times to enable inferences about RGSM abundance and distribution in the MRG. The Monitoring Program could also be improved by increasing site lengths, effort per site, or number of sites.

In general, the Expert Panelists concluded that the statistical analyses currently used in the Monitoring Program are appropriate given the distribution and characteristics of the CPUE data, which exhibit a high frequency of zeros and non-normal frequency distributions of the non-zero catches. The Monitoring Program uses the mixture model approach to address these distributional characteristics and to permit estimation of CPUE from the catch and effort data. Mixture models are flexible and allow consideration of the effects of factors such as year, mesohabitat type, and hydraulic variables on both the presence and CPUE of RGSM in the system. Mixture models are more informative than previously applied approaches. We believe that mixture models provide a reasonable statistical tool for assessing the effects of hydrological variables, and the availability of mesohabitat types on CPUE; furthermore, mixture models lead to better understanding of the habitat conditions necessary for persistence and annual recruitment of RGSM in the MRG. Currently, there are confounding effects of environmental variability and stocking of hatchery fish that must be disentangled in assessments of the effects of hydrologic and habitat features on RGSM in the MRG.

Additional analytical techniques may be explored, but it is unclear if such approaches would reduce bias or improve precision of estimates of CPUE. Comparative analyses or simulation studies are needed to ascertain if analytical improvements can be obtained and the possible magnitude of potential improvements. We recommend examination of the underlying assumptions of the mixture model and interpretation of results in light of these assumptions. The assumption of constant effort among sites and the assumption of constant, proportional effort among mesohabitat types that are currently made in the calculation of CPUE for RGSM should be examined. The processes that give rise to the zeros in the datasets from which CPUEs are calculated warrant further consideration. Dynamic features of the MRG, such as the spatial and temporal extent of drying events, need to be assessed and considered as factors affecting observed catch rates. Approaches such as classification and regression trees, boosted regression trees, or random forests may be used to elucidate the relationship between CPUE of RGSM and hydrologic conditions in the river; these approaches are particularly useful for identifying thresholds of response. Insights on the persistence, colonization, and extinction rates of RGSM can be derived from the Population Estimation Program; this approach should be continued, but we emphasize that such sampling is in addition to the current Monitoring Program.

1.0 Introduction

The Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) is comprised of multiple stakeholders representing diverse interests related to water operations and management within the Middle Rio Grande (MRG), New Mexico. The MRG is the section of the Rio Grande in New Mexico between Cochiti Dam and Elephant Butte Reservoir. The Collaborative Program works to comply with the Endangered Species Act and supports the recovery of the federally listed species that occupy this reach, with special emphasis on the Rio Grande Silvery Minnow (*Hybognathus amarus*; RGSM) and the Southwestern Willow Flycatcher (*Empidonax traillii extimus*). Simultaneously, the Collaborative Program works to protect existing and future water uses while complying with applicable state and federal laws, rules, and regulations. The Collaborative Program is transitioning to become a Recovery Implementation Program (RIP), and will be establishing sufficient progress metrics for the RIP that may include species demographics.

Population monitoring of the RGSM began in 1993 and has been carried out every year since, except for 1998 (Dudley and Platania 2011). The RGSM was listed under the Endangered Species Act as endangered in 1994. The Monitoring Program provides annual, as well as nearly monthly, CPUE estimates of small-bodied fishes in the MRG.

As part of a transition to a RIP, the Collaborative Program is beginning its review of the Monitoring Program, including its indices and methodologies. The Monitoring Program has provided the U.S. Fish and Wildlife Service and the Collaborative Program with an index of fish abundance and population trends in the portion of the MRG between Angostura Diversion Dam and Elephant Butte Reservoir. However, there is disagreement among the parties of the Collaborative Program regarding whether the status and trend information from the Monitoring Program fully meet the needs of the Collaborative Program. To address these concerns, the Collaborative Program formed an *ad hoc* Population Monitoring Workshop Planning Workgroup (Planning Workgroup) to evaluate the current Monitoring Program and to set up a process for establishing the RIP's fish monitoring program. A work plan was approved by the Collaborative Program that included a workshop to address the current CPUE methodologies and sampling design as its first step in refining the Monitoring Program.

The Collaborative Program conducted a Fish Population Monitoring Workshop (Workshop), described herein, that resulted in this summary report. This report was prepared by knowledgeable experts in the fields of fisheries science, fish sampling methodologies, and statistical analyses. The panelists also have experience with fisheries issues associated with the Endangered Species Act. The recommendations from this report are available to assist the Collaborative Program in its fish-monitoring program. The purpose of the Workshop was to discuss and resolve outstanding questions, gain external opinions on issues identified by the Collaborative Program, and receive external recommendations on the current methods and indices used. The external opinions contained herein were developed to be objective and to provide recommendations for consideration by the Collaborative Program. This report is organized to address four primary questions, as developed by the Planning Workgroup.

---

(1) Is the CPUE index appropriate for monitoring the Rio Grande Silvery Minnow in the Middle Rio Grande?

(2) Are the monitoring plan and sampling design appropriate for tracking the status and trend of the RGSM in the Middle Rio Grande?

(3) A. Are the statistical analyses used in the Monitoring Program appropriate and in line with data distributions and characteristics?
(3) B. Are there additional analytical techniques that could be used that would improve the use of CPUE?

(4) What revision can be made to the sampling design to improve accuracy, precision, and power to detect change in RGSM abundance?

The panelists addressed each of the four primary questions within this report. Additionally, the panelists provided observations regarding the Collaborative Program that go beyond the four primary questions in a separate section of the report (Section 7.0 - Observations beyond the scope of the Population Monitoring Workshop).

1.1 Workshop Logistics

The Workshop was conducted at Isleta Casino and Resort, 11000 Broadway Boulevard SE, Albuquerque, NM 87105. The workshop was held on 8-10 December 2015. All logistics for the workshop were coordinated by Matthew Cusack of Atkins. The workshop was held the first morning in the Seminar Room, but because of poor acoustics in that room, the workshop was relocated to the Manzano/Sunrise Rooms that had been combined into one space to accommodate the workshop layout. The workshop layout was organized as depicted in the agenda (see Appendix A), with the technical experts and external panelists seated at the workshop table and interested observers seated behind the table on three sides.

The original workshop agenda was prepared by the Working Group members. The workshop facilitator, Dr. Wayne Hubert, was given an opportunity to adjust the agenda and the schedule of the workshop. The final agenda of the workshop is available as Appendix A. A series of ground rules was prepared by Dr. Hubert and submitted to the Working Group in advance of the workshop to gain their feedback and approval (Appendix B). The Working Group members approved the ground rules in a meeting on 9 November 2015.

The focus of the workshop was to conduct a professional and technical conversation regarding the status of the Monitoring Program, as well as to answer four key questions (Appendix C). Sub-questions associated with each key question were developed by the Planning Workgroup to provide additional context to the primary questions rather than to be explicitly addressed themselves. The workshop was developed and facilitated in a manner deemed most likely to provide clear and consistent dialogue among the workshop participants about each primary question. An additional benefit of addressing each of the four questions separately in the agenda was to ensure that only one question was being addressed at a time, to reduce confusion, and to minimize disjointed dialogue that would interfere with recording and continuity. The format of the workshop also enabled the expert panelists to provide their opinions in this report in a manner that is both clear and organized.

In advance of the workshop the expert panelists were provided with data sets along with relevant documents and publications. The materials were carefully selected by consensus of the Planning Workgroup, and the expert panelists were requested to prepare for the workshop by reviewing the provided materials (Appendix D). Other materials were provided by participants during the workshop, but only the selected works, the dialogue from within the workshop, and the references listed in this report (see Section 8) were used by the expert panelists in developing the recommendations provided in this report (see Section 6).

The workshop was open to the public; however, the invited workshop participants were technical experts representing numerous Collaborative Program signatories (Table 1). Daily sign-in sheets were collected (Appendix E) and every attempt was made to ensure that every person who attended the workshop signed in regardless of whether they were a participant (at the table) or an observer.

The external scientists provided by Atkins were selected from a pool of nationally recognized experts that the Planning Workgroup had pre-qualified during the contracting process with Atkins. It was deemed essential by the Collaborative Program that the Workshop include expert scientists who have expertise in the subject matter and would bring in new perspectives and objective viewpoints to the Workshop proceedings.

Table 1. Technical Participants at the Rio Grande Silvery Minnow Population Monitoring Workshop

Representative	**Agency**
Rick Billings	ABCWUA; Albuquerque Bernalillo County Water Utility Authority
Robert Dudley	ASIR; American Southwest Ichthyological Researchers
Gary White	ASIR; American Southwest Ichthyological Researchers
Mike Marcus	APA; Assessment Payers Association
Ben Cogdell	Atkins
Matt Cusack	Atkins
Mark McKinstry	BOR; Bureau of Reclamation
Kathy Lang	COA; City of Albuquerque
Bob Hughes	Expert Panelist
Wayne Hubert	Expert Panelist
Mary Fabrizio	Expert Panelist
Bill Pine	MRGCD; Middle Rio Grande Conservancy District / University of Florida
Rich Valdez	NMISC; New Mexico Interstate Stream Commission
Scott Bulgrin	Pueblo of Sandia
Michael Porter	USACE; United States Army Corps of Engineers
Thomas Archdeacon	USFWS; United States Fish and Wildlife Service

In accordance with the ground rules for the workshop (see Appendix B), every attempt was made to ensure that all comments and questions were directed at the meeting facilitator to avoid cross conversations, arguments amongst participants, or distracting conversations that could not be heard by all participants and observers attending the workshop. Written notes and statements were collected by Atkins during the workshop, with the notes presented on a screen made available to all attendees to ensure that complicated or long statements were accurately captured for review by the expert panelists during the development of this report. The questions and statements from Days 01 and 02 (8 and 9 December) are provided as Appendix F. After the four primary questions were addressed in the workshop, the expert panelists and Atkins met during the evening of 9 December and the morning of 10 December to develop preliminary conclusions. The preliminary conclusions were presented to all meeting attendees later in the morning on 10 December. The afternoon of 10 December included open comments and questions from any meeting participant or observer (Appendix G).

This document was originally prepared in draft form and circulated to workshop participants (see Table 1) for review and comment. Comments were organized by program, and provided to the expert panelists in a detailed comment matrix prepared by Atkins. The expert panelists addressed each comment provided in the matrix, and provided the draft comment matrix back to the commenters. Atkins hosted a screen sharing teleconference with the Working Group, and they were given an opportunity to restate or clarify their comments in the event that the comment matrix indicated that their comments were not specifically addressed. The expert panelists considered all of this feedback when developing this final report. The draft report, the final comment matrix, and the notes from the teleconference call are available as part of the administrative record for this project.

Understanding the logistics of the workshop and this resulting summary report are important to provide the necessary context regarding the findings and recommendations of the expert panelists. For the remainder of this document, the expert panelists address each of the four primary questions, provide context to questions and statements entered into the record during the workshop (when necessary), and provide their overall recommendations and observations for the Collaborative Program to consider.

2.0 Population Monitoring Workgroup Question 1

1. Is the CPUE index appropriate for monitoring the Rio Grande Silvery Minnow in the Middle Rio Grande?

The expert panelists concluded that CPUE indices are appropriate for monitoring RGSM in the MRG, but the indices may be improved if the current data recording and computational techniques are modified as described below.

2.1 Definition of catch per unit effort (CPUE)

Most common fish abundance indices are computed from CPUE data for samples from a fish population (Hubert and Fabrizio 2007). A CPUE index is defined mathematically as $C/f = qN$, where C is the number of fish caught, f is the unit of effort expended, q is the catchability coefficient or probability of catching an individual fish in one unit of effort, and N is the absolute abundance of fish in the population.

Because absolute numerical abundance is extremely difficult and expensive to estimate, fisheries scientists often use CPUE indices to make judgments about the abundance of fish in a population.

2.2 Definition of the MRG fish population in the Monitoring Program

In the case of the Monitoring Program, the RGSM population of concern occurs within the MRG from Angostura Diversion Dam downstream to where the river meets Elephant Butte Reservoir. The entire population of the RGSM is not the focus of the Monitoring Program. The entire RGSM population may also include fish occurring upstream (above Angostura Diversion Dam), downstream (in Elephant Butte Reservoir), in tributaries, and in portions of irrigation and water delivery systems. The objective of the Monitoring Program is to monitor fish only in the MRG between Angostura Diversion Dam and Elephant Butte Reservoir and to facilitate inferences about the population between Angostura Diversion Dam and Elephant Butte Reservoir.

When the Monitoring Program was initiated in 1993, the objective was to monitor status and trends of wild RGSM that were spawned in the MRG and that lived in the MRG throughout their lives. In recent years, cultured RGSM have been introduced annually to the MRG. The progeny of cultured fish cannot be distinguished from fully wild fish when sampled. Consequently, the Monitoring Program is currently monitoring status and trends of a mixed population of wild fish, marked hatchery fish, and the progeny of hatchery fish without the ability to distinguish the progeny of hatchery fish from wild fish.

2.3 Sampling gears used in the Monitoring Program

Seines are widely used to sample fish and are particularly useful for sampling small fishes in wadeable, debris-free portions of streams and rivers (Bonar et al. 2009). Catch (C) is defined as the number of fish caught of a given species, life stage, or size class (e.g., age-0 RGSM). The chosen gears for the Monitoring Program are two kinds of seines. The small-mesh seine is 3.1 m long by 1.8 m wide with 5-mm mesh. The other is a fine-mesh seine that is 1.0 m long by 1.0 m wide with 1.5 mm mesh. The small-mesh seine is designed to catch larger fish, whereas the fine-mesh seine is designed to catch larval fish. Because the gears are selective for different size classes of the RGSM population, the catchability coefficients (q) differ between the small-mesh seine and the fine-mesh seine. Consequently, it is inaccurate to combine the catch (C) from the two gears into a single CPUE index. Separation of CPUE estimates by gear type enables understanding of status and trends of specific RGSM life stages (i.e., larval fish versus age-0 and larger fish).

2.4 Standardization of catch rates

In the Monitoring Program, the unit of effort (f) is the total area over which a seine is hauled within a sampling site during a specific sampling event. For the small-mesh seine, the area is computed as the total distance of all seine hauls multiplied by the width of the seine as it is being pulled (i.e., 2.5 m). Similarly, for the fine-mesh seine, the area is computed as the total distance of all seine hauls multiplied by the width of the seine as it is being pulled (0.25 m). To standardize catch rates, the Monitoring Program uses catch and effort data to express CPUE as the number of fish caught per 100 square meters (m^2) seined during an individual sampling event at a sampling site. For example, if 50 fish were captured in 20 seine hauls covering 500 m^2, the CPUE would be recorded as 10 fish/100 m^2. However, use of a common CPUE metric (i.e., fish/100m^2) for both small-mesh and fine-mesh seines does not allow for data from the two types of seines to be combined into a single CPUE because of the differing selectivity (i.e., catchability coefficients) of each type of seine. See Sections 2.5, 2.6, and 4.11 for more detail.

2.5 Sampling effort in the presence of dry sites

The absence of water at a sampling site may provide a signal that fish are absent, but such an observation does not provide CPUE data and should not be recorded as a true zero in CPUE datasets (See Section 4.11 for more detail). Effort (*f*) must be expended to obtain CPUE data. For example, when sampling with seines in the MRG, if seining is not possible at a site because of drying or extremely low flows, then no effort (*f*) is expended and no CPUE data are obtained. In these cases, the Population Monitoring Program assumed that because the site was dry, no fish were present, and the number of RGSM observed at the site was recorded as a zero for analytical purposes. Consequently, in data analyses a distinction is not made between zero CPUE at sites with water that were sampled and zero CPUE at sites that were dry and not sampled. In the Population Monitoring Program, the zeros associated with dry sites constitute what have been called 'naughty naughts' (also see Sections 3.2, 3.3, 4.10, and 4.12; Martin et al. 2005), a special type of zero observation. The manner in which these naughty naughts are handled is critical; zero observations from dry sites **should not** be included in computations of CPUE (Zuur et al. 2009). Naughty naughts arise when sampling is conducted in an area where the probability of encountering an individual is zero, regardless of the sampling design or method used. For example, sampling for RGSM in the Sacramento River would result in zero RGSM at all sites; these naughty naughts occur outside the environmental range of the species (Martin et al. 2005) and cannot provide information on relative abundance or occurrence of the species. If the probability of encountering an individual in a given area is zero because the area is outside the species' range, then those areas are not part of the survey-sampling domain, and those naughty naughts should be ignored in CPUE computations. The presence of naughty naughts is a strong indication that the fixed-site survey design is not adequate at times when dry sampling sites occur in the MRG (see Section 3.2; Martin et al. 2005).

Information obtained from American Southwest Ichthyological Researchers, the organization that conducts the Monitoring Program on the MRG, indicates that field data records, and the database in which the data are stored, differentiate zeros at dry sampling sites and zero catches from sites that were sampled but which yielded no RGSM. The issue of naughty naughts occurs during statistical analyses, when the distinction is lost, and the two types of observations (zeros at dry sampling sites, and zero catches from sites where sampling was conducted and no RGSM were captured) are treated in the same manner.

2.6 Age composition of the catch

The small-mesh seine captures primarily age-0 (spawned in early summer) RGSM once they have grown to a size that is retained by the small-mesh seine. Age-0 fish are susceptible to capture beginning in late summer and continuing through the remainder of the calendar year (Dudley et al 2015). In January of the following calendar year, these fish are designated as age-1 (per standard fishery aging conventions); however, in January, RGSM in the MRG are not yet a full 1 year of age (i.e., they have lived less than 12 months). The small-mesh seine captures these age-1 RGSM in February to May samples along with a few older RGSMs. Few RGSM older than age-1 are captured at any time of the year. Consequently, the CPUE of RGSM captured in the small-mesh seine is primarily an index of abundance of age-0 fish in the fall of the year and age-1 fish early in the following year (i.e., the abundance of the most recent cohort). A more accurate and precise CPUE index for a particular year's cohort of RGSM could be obtained if older fish were separated from the catch (*C*) of the most recent cohort. This improved small-mesh seine CPUE index has the potential to provide better insight into several demographic parameters of RGSM in the

MRG: survival through the first year of life, magnitude of recruitment to the population of sexually mature spawners, and abundance of the most recent cohort. A separate CPUE index could be computed for older cohorts using length frequencies to delineate age classes. However, we recognize that age-length relationships for RGSM in the MRG have not been resolved.

2.7 Multiple sampling gears and CPUE

Our evaluation of Dudley et al. (2015), particularly Appendix D, and the database (i.e., Copy of Provisional _RGSM_Pop_Mon_Database_1993-2014) indicates that catch and effort data with each type of seine for April to October sampling events are combined to yield a single CPUE index for each sampled site on each sampling event. The manner in which the catch and effort data are summarized in annual reports does not distinguish the fish caught with the small-mesh seine from those captured with the fine-mesh seine, nor does it report CPUE specific to those gears, or identify individual length classes captured with those gears. We consider this a serious computational error (see Section 2.3).

The fine-mesh seine is designed to capture larval fish, but occasionally captures larger fish. Again, the catch and effort data with the fine-mesh seine should be analyzed separately from catch and effort data from the small mesh seine because CPUE indices computed from those data are unique to each gear type. Additionally, because the fine mesh seine is selective for larval fish, only larval fish should be included as catch (C) in the computation of these CPUE indices and only the seine hauls with the fine-mesh seine should be included in the computation of effort (f) for that gear. A more accurate and precise fine-mesh seine CPUE index has the potential to provide insight into hatching dates, magnitude of spawning success, and potential cohort abundance of RGSM in the MRG. Similarly, the small-mesh seine is designed to capture larger fish and the data from this gear type should be used separately to compute CPUE for the most recent cohort (see Section 2.3).

2.8 Factors affecting the catchability coefficient of sampling gears

Variation in the catchability coefficient (q) of a particular type of seine can be affected by the mesohabitat in which sampling occurs. Variation in the catchability coefficient can result from features of the mesohabitat type (e.g., water depth, current velocity, substrate composition, etc.) and the affinity of fish for particular mesohabitat types. The Monitoring Program protocols involve sampling several mesohabitat types at a site, but the catches from distinct mesohabitats are pooled in a single index of CPUE. Dudley et al. (2015) state, “Runs and shorelines were sampled four times at each site (when available); backwaters, pools, and riffles were sampled two times (when available); any remaining samples (to obtain a total of 18 to 20) were taken in shoreline runs.” These protocols fail to account for the proportions of various mesohabitat types sampled, variation in the catchability coefficient among mesohabitat types, and the affinity of fish for particular mesohabitats. The current Monitoring Program protocols do not account for this source of variation in the computation of CPUE indices. It is likely that the CPUE values are biased by the proportion of sampling in particular mesohabitat types. Numerous scenarios could be described to demonstrate the potential for bias. For example, it can be hypothesized that at a site where there are no backwaters or pools and only runs and shoreline mesohabitats at the time of sampling, the catchability coefficient and subsequent catch would be lower than at a site where backwater and pool mesohabitats (assumed preferred habitat by RGSM) are present and sampled. The effects of variation in the availability mesohabitat types and variation in catchability of RGSM among mesohabitat types are not addressed using the current protocols (see Section 4.10 for a suggested statistical approach to address this problem).

The catchability coefficient is also affected by environmental factors (e.g., turbidity, water temperature, and current velocities). Although several environmental factors are measured when sites are sampled during the Monitoring Program, there has been limited assessment as to how those factors may affect the variability of the catchability coefficient of a gear. It appears that the Monitoring Program assumes that environmental factors have little influence on the catchability coefficient of the sampling gears. Better understanding of the influence of measurable environmental factors on the catchability coefficient of each seine type used in the MRG could reduce the uncontrolled variation among samples and improve both the accuracy and precision of CPUE estimates (see Sections 4.3 and 5.2 for more detail).

Another source of variation in the catchability coefficient of a gear is related to how sampling gears are operated by sampling crews. When using seines, such variability can be associated with the length of seine hauls, how seines are operated or lifted at the end of hauls, the speed at which seines are hauled, the direction of hauls relative to river currents, how data are recorded when seine hauls are interrupted by snagging, and many other factors. The operation of the seines by sampling crews of the Monitoring Program appears to be highly standardized with little variation among sampling years. The same crew leader has been involved since the beginning of the Monitoring Program.

It is recognized that the RGSM tends to be a schooling species. The effect of this behavior on CPUE data is likely to be high variation in CPUE among individual seine hauls and sites, and variation in capture efficiency among different mesohabitat types. Constrained mesohabitats, such as small backwater areas, from which fish cannot readily escape, are likely to yield higher CPUEs than other mesohabitat types. To address this variation, we recommend the continued examination of CPUE data by mesohabitat type. We caution that mesohabitat types and the schooling behavior of RGSM may be confounded, and that directed studies may be needed to determine if relationships exist.

2.9 The assumption that CPUE is a function of abundance (i.e., $C/f = qN$)

A major assumption of a CPUE index is that it is related to the abundance (N) or density (N/A) of fish, where N is the absolute abundance of fish in the population and A is the area over which the population occurs. Dudley et al. (2012) compared the CPUE of RGSM in the fall to an independent index of density obtained at the same time in the MRG over a 4-year period and found a positive relationship between the two indices. However, they concluded from a simulation analysis that "a strong correlation between the Population Estimation Program and Population Monitoring Program data is **unlikely** to persist over time." Consequently, it may be considered reasonable that CPUE from the Monitoring Program provides a signal of year-to-year variation in density of age-0 and older RGSM in the MRG, but that relationship may not persist in all years. When October sampling is conducted to provide a CPUE index for year-to-year assessment of trends, RGSM catches are predominantly age-0 fish, suggesting that the CPUE index is primarily an index of density of age-0 fish. However, it must be recognized that the variation in CPUE among some years is quite large (i.e., orders of magnitude) and that the CPUE index used in the analyses by Dudley et al. (2012) did not differentiate catch and effort between the two types of seines or among mesohabitat types. Computation of separate CPUE indices for each of the two gear types would yield insight as to whether the variation in CPUE among sampling periods within a year or from year-to-year for a particular sampling period is due to variation in the abundance of larval fish or age-0 and older fish.

2.10 Alternative sampling gears

It was asked if seines are the best gear for sampling RGSM to obtain an index of relative abundance. Other gear types, such as minnow traps and small fyke nets (Hubert 1996) were suggested during the workshop, because they may have higher catchabilities for larger RGSM, especially in mesohabitats with woody debris, rooted vegetation, filamentous algae, and other obstacles to seining. Minnow traps and fyke nets are passive gears, meaning they are not actively moved by humans while fish are captured, and capture depends on the movements and behavior of fish. It is the experience of the expert panelists that the efficiency of capturing small, stream-dwelling fishes with minnow traps and small fyke nets is likely to be low. Further, a wide array of environmental variables (i.e., season, water temperature, time of day, water-level fluctuation, turbidity, and currents) can influence CPUE with passive gears and lead to high variability in CPUE (Hubert et al. 2012). Behavior of fishes, such as schooling, migration, or crepuscular activity, also contributes to variation in CPUE estimates from passive gears (Hubert and Fabrizio 2007). Substantial research on the factors affecting catchability and selectivity of alternative gears is needed before they are added to the current Monitoring Program.

2.11 Appropriate use of CPUE indices as recovery standards

Measures of CPUE for RGSM from the MRG are currently identified as recovery standards for the species. This is a reasonable use of CPUE indices. However, the description of recovery standards should be explicit regarding gear, sampling design, sampling techniques, data analysis, and life stage, as well as protocols used to compute the CPUE index. Although the workshop did not explicitly address the utility of CPUE for the purposes of recovery standards, the current recovery standards could be improved with the computation of more accurate and precise CPUE indices from the current monitoring program data. Primary among the recommendations of the expert panelists is computation of CPUE indices separately for each gear type and omission of naughty naughts (i.e., dry sampling sites where fish are not sampled) from computations of CPUE. Further, the observation of dry sampling sites during some sampling periods indicates that the fixed-station survey design is not adequate at times when dry sampling sites occur in the MRG (see Sections 3.2 and 5.3; Martin et al. 2005).

3.0 Population Monitoring Workgroup Question 2

2. Are the monitoring plan and sampling design appropriate for tracking the status and trend of the RGSM in the Middle Rio Grande?

The panelists concluded that the monitoring plan and sampling design with the small-mesh seines are appropriate for tracking the status and trends in abundance and occurrence of the most recent cohort of RGSM (see Section 2.6) except when sampling sites are observed to be dry. Similarly, the monitoring plan and sampling design for fine-mesh seines are appropriate for larval RGSM, but may also produce naughty naughts when dry sampling sites are observed (also see Sections 2.5 and 4.12). The panelists identified five considerations for survey designs applicable to the Population Monitoring program: (1) random versus non-random site selection, (2) fixed-site versus variable-site sampling, (3) adequate sample size, (4) sub-population inclusion, and (5) consistent site-scale sampling protocols sufficient to capture natural habitat variability.

3.1. Random versus non-random or stratified site selection

To allow inferences for an entire river or river reach without bias, a randomized survey sampling design is generally recommended (Olsen & Peck 2008; Angradi et al. 2009; Hughes et al. 2012). For example, Hughes et al. (2000) reported that Oregon coho salmon escapement was substantially overestimated when using handpicked sites to which fish were known to return reliably compared with escapement estimated from randomly selected sites. Similarly, markedly different results were obtained from randomly and non-randomly selected sites regarding characterization of lakes in the northeast USA as eutrophic/hypereutrophic (Hughes et al. 2000).

Random site selection enables calculation of confidence bounds around estimates of means or medians that are as useful for making population or assemblage assessments (Hughes et al. 2000; Paulsen et al. 2008; Dudley et al. 2012). However, two independent 20-site studies in 2006-2008 and 2014 employing a GRTS (Generalized Randomized Tessellated Stratified) design (i.e., random site selection) and population estimation based on multiple-depletion sampling yielded similar annual patterns in RGSM abundance as those produced from the 20-fixed-site survey used by the Monitoring Program (Dudley et al. 2012; Archdeacon et al. 2015). This suggests that the non-random fixed-site sampling employed by the Monitoring Program may provide a reasonably accurate representation of trends in RGSM abundance given the discharges occurring during the years of those studies. However, Dudley et al. (2012) concluded from a simulation analysis that “a strong correlation between the Population Estimation Program and Population Monitoring Program data is **unlikely** to persist over time.” In the Dudley et al. (2012) study, one randomly selected site had to be replaced with another because of anthropogenic channel alterations that precluded sampling. In the Archdeacon et al. (2015) study, two sites were dry in the summer, not sampled, and not replaced with wetted random sites. Archdeacon et al. (2015) estimated a CPUE of 0.08 RGSM/100 m^2 (95% confidence interval: 0.04-0.18) from the random survey compared with a CPUE of 0 from the non-random survey. In both the Dudley et al. (2012) and Archdeacon et al. (2015) studies, some selected sampling sites could not be sampled due to dry conditions exemplifying the problem of the frequent occurrence of dry sampling sites in the MRG.

Options for the Monitoring Program may be a stratified random or stratified non-random survey design, where strata are defined according to mesohabitat type (i.e., riffle, run, shoreline run, pool, shoreline pool, backwater, shoreline backwater). However, to provide statistically reliable data for each stratum, the total number of randomly selected sampling sites needed would be 20 to 50 times (Hughes & Peck 2008; Olson & Peck 2008) the number of strata (i.e., the number of mesohabitat types). In the case of the MRG, that number could be 140 to 350 (7 mesohabitat types times 20 to 50). The total number of strata and sites could be reduced to two strata and 40 to 100 sites, respectively, by merging mesohabitat types into faster water (riffle, run, shoreline run) and slower water (pool, shoreline pool, backwater, shoreline backwater), or to only one stratum and 20 to 50 if only slower water (more productive) habitats were sampled.

3.2 Fixed-site versus variable-site sampling

Fixed-site survey designs, such as that employed by the Monitoring Program, usually provide CPUE (and other) data with less variance than variable-site designs. Use of a variable-site design can add an additional, and potentially sizeable, site component of variance (Anlauf et al. 2011). This is because spatial variability among sites can account for more variability than measurement, year, or site-by-year interaction variance in aquatic ecosystems (Anlauf et al. 2011). Therefore, fixed-site designs can provide earlier long-term trend detection than can variable-site designs (Larsen et al. 2004). This is a strength of the Monitoring Program—as long as the sites are watered and capable of being sampled. The Monitoring Program has demonstrated the ability to sample the same set of fixed sites on a nearly monthly and yearly basis, which is a critically important consideration for a long-term, trend-detection monitoring program (Larsen et al. 2004; Anlauf et al. 2011). However, a fixed-site design is useful and appropriate only when those sites are sampleable (i.e., inferences to the RGSM population cannot be made if sites are not sampled; Olsen & Peck 2008). Sites that cannot be sampled for fish during dry months or dry years add measurement variance to population monitoring estimates if those sites are retained and identified as zero CPUE values in data sets (i.e., naughty naughts; see Sections 2.5. 3.2, and 4.12, and 5.1; Martin et al. 2005), and they effectively reduce the sample size for population monitoring if they are not replaced with another site (see Sections 2.5, 3.3, and 4.12). Regardless of the survey design, a related problem occurs when flows fluctuate from dry to recently wetted. Depending on the time elapsed since rewetting, such sites may not support RGSM; however, if they support other fishes, they can be assumed to be suitable habitat for RGSM. Nonetheless, the fixed or variable sites that are dry or recently wetted (and potentially unoccupied by fish) should be recorded as an important indicator of habitat unsuitability for RGSM. However, care must be taken in how these sites are recorded in databases and used in computation and analyses of CPUE data.

3.3 Sample size

It has been established that the greater the number of randomly selected sampling sites, the greater the accuracy and precision of status and trend estimates (Larsen et al. 2004; Smith & Jones 2005; Olsen & Peck 2008; Anlauf et al. 2011). This is because the increasing sample sizes or number of sample sites reduces the among-site variance as well as the site-by-year interaction variance and residual or unexplained variance (Figure 1).

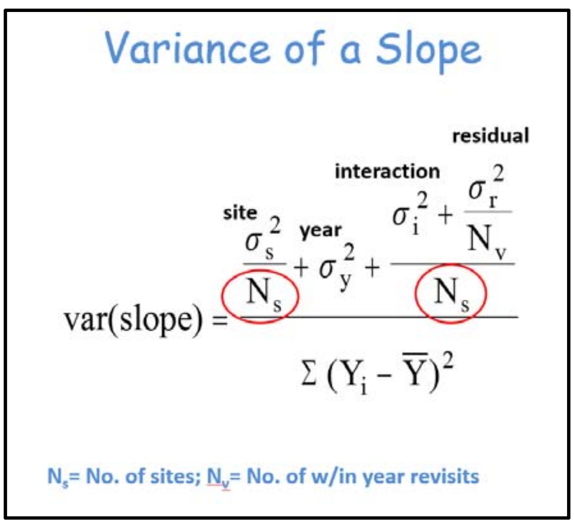


Figure 1. Effects of sample size (number of sites) on the variance of a slope (modified from Larsen et al. 2004)

Statistically and logistically, an ideal number of sites for making population estimates is approximately 50 sites per reporting unit (Hughes & Peck 2008; Olson & Peck 2008). The fixed-site survey design and the drying of sampling sites in the MRG results in naughty naughts that must not be included in the calculation of annual mean CPUEs (see Sections 2.5, 3.2, and 4.12). Although this approach appears to result in estimates that are biased high, the naughty naughts are not true zeros because naughty-naughts are obtained from areas that have a zero probability of supporting RGSM (and, in this case, other aquatic organisms). However, observations from wetted sites have non-zero probabilities of supporting RGSM, that is, there is a probability that fish occur at the site. These disparate probabilities are not accommodated in the fixed-station survey design, and thus, the presence of drying in the MRG warrants reconsideration of the survey design when dry sampling sites occur. However, the proportion of the reach (or river) that is dry (indexed for example, by the number of dry sampling sites) is an indicator of aquatic habitat availability and, thus, of use when interpreting estimates of mean CPUE.

Understanding the processes contributing to annual fluctuations in the relative abundance (CPUE) of RGSM requires careful consideration of the survey design, particularly with regard to dry sampling sites. Consider the case where the mean CPUE estimated by sampling in October is zero (that is, no fish were observed in a given year). In this situation, additional information is required to properly interpret this observation and make comparisons with mean CPUE estimates from other years. In particular, the lack of fish may indicate that: (1) a population crash occurred despite consistent flows, (2) all sites were dry at the time of sampling, (3) all sites were dry immediately prior to sampling and fish had not yet recolonized or been stocked, or (4) something else occurred. The proportion of the river that exhibits drying can be used to infer habitat-related causes of population declines or fluctuations. This is precisely the type of information that should not be lost by coding dry sampling sites as zero CPUE values and erroneously including these naughty naughts in the calculation of mean annual CPUEs.

Although the MRG has been subject historically to channel drying, such events appear to be limited in time or restricted to portions of the river (Cowley 2002). Drying events appear to be dynamic features of this system and, thus, may not be consistent from year to year or throughout the MRG. Thus, the spatial and temporal extent of drying events need to be measured (annually by month) and considered as factors affecting observed catch rates and distributions of fish. If such data are not available, suitable proxies, such as peak spring discharge (Written Record 03) or amount of water released by the MRG Conservation District (Written Statement 02) could be considered. Another approach to assess habitat conditions in the MRG may be the use of low altitude aircraft with geolocation and video capabilities (see e.g., http://www.fishdata.org/blog/digital-revolution-drones, and http://portlandtribune.com/wlt/95-news/246263-113905-oregon-will-use-drones-to-collect-data-on-fish-birds). Flights over 150 miles of the MRG could be completed in one day, and wet and dry segments of the river could be delineated from digital images. However, such use must be considered in light of federal and state regulations and restrictions.

Several comprehensive studies of recommended sample sizes have been produced in the USA. Olsen and Peck (2008) recommended sampling 50 sites per reporting unit based on the US Environmental Protection Agency's National Rivers and Streams Assessment. Smith and Jones (2005) reported that for Wisconsin rivers and streams, 30 to 98 (mean of 49) sites were needed to detect 95% of the estimated species present, and 76-151 (mean of 119) sites were needed to detect 100% of the estimated species present. For common species in Kansas and Nebraska wadeable streams and rivers, Fischer and Paukert (2000) found that 63 to 994 sites must be sampled to detect a 25% change in CPUE at a power level of 0.9. To detect 100% of all species per 20- to 30-km-long segment, Fischer and Paukert (2000) determined that 10 sites covering 400 to 600 mean stream widths were needed in streams 10 to 29 m wide. In other words, the number of sites that need to be sampled to detect rare, patchy, or uncommonly encountered species in a river can be considerable. However, 20 sites is a reasonable sample size for balancing statistics and logistics (Hughes & Peck 2008) when assessing status and trends of common species in a river the length and mean wetted width of the MRG (Hughes & Gammon 1987; LaVigne et al. 2008; Hughes et al. 2012). Nonetheless, a substantially greater number of sites would improve the confidence in, and accuracy of, both CPUE estimates and the spatial distribution of RGSM in the MRG—especially when CPUE estimates are very low or zero and sites are many kilometers apart (Gammon 1995; Larsen et al. 2004; Olsen & Peck 2008). The ideal number of sites is best determined by assessing the current variance in CPUE estimates over the times of concern, determining the desired confidence bounds in CPUE estimates (especially when CPUE is very low or zero), conducting power analyses to estimate the number of sites needed given those conditions, and then deciding how much the Collaborative Program wants to spend on long-term CPUE monitoring (Hughes & Peck 2008; Olsen & Peck 2008; see Section 5.1).

3.4 Sub-group inclusion

In large-scale monitoring programs, it is useful to have a sampling design sufficiently flexible to facilitate sub-group assessments (Olsen & Peck 2008). As long as sites are well wetted, there is a reasonable spatial distribution of fixed sites throughout the MRG and within the three reaches, which are congruent with the manner in which the river has been segmented for water management purposes. However, there are far too few sites per reach for reliable status and trend estimates at the reach (sub-group) scale (Gammon 1995; Olsen & Peck 2008; Angradi et al. 2009). As described previously, 20 to 50 sites per reporting unit (reach in this case) are needed for statistically rigorous assessments of each reach or for making reach-specific assessments of management actions (see Figure 1). The results presented in Dudley et al. (2015) do indicate reach-scale differences, but the statistical uncertainties of these estimates need to be acknowledged. With appropriate caveats, these estimates may be useful for making qualitative reach-scale management decisions regarding water flow regimes and physical habitat structure. However, much larger sample sizes are needed to yield statistically reliable CPUE indices for individual reaches.

3.5 Site-scale sampling protocol

Site-scale sampling designs are a compromise between science, logistics, and temporal and fiscal realities (Hughes & Peck 2008). An important strength of the Monitoring Program is that its design incorporates effective sampling across available and spatially variable mesohabitats encountered at a wide range of discharges. The selection of the October index period for annual assessments is appropriate because base low flows at that time are relatively stable in most years. However, many sites produce no RGSM. This may occur because RGSM are discontinuously distributed, because the species avoids or prefers particular habitats, or because the species is rare, which may result from truly low population density, or insufficient, inefficient, or inadequate sampling (Kanno et al. 2009). Fischer and Paukert (2009) found that the number of sites needed to estimate species richness in 20- to 28-km-long stream segments decreased as site length increased from 10 to 60 mean stream widths. Hughes et al. (2002) sampled each of 45 Oregon river sites that were 100 times the mean wetted channel width (MWCW); sites ranged from 7 to 210 m wide (mean of 52 m), and they found that a site length of 85 MWCWs yielded 95% of estimated true fish species richness (Colwell 1997), which was about 0 to 3 species fewer than estimated. The U.S. Environmental Protection Agency's National Rivers and Streams Assessment and others recommend site lengths of 40 to 100 MWCWs (Hughes & Peck 2008). Leopold et al. (1964) estimated that 20 MWCWs usually incorporated one or more meander cycles, and therefore most stream mesohabitat types. Following Leopold et al. (1964), the U.S. Geological Survey's National Water Quality Assessment uses 20 MWCWs to set site lengths initially, but with minima and maxima of 500 m and 1 km, respectively (Meador et al. 1993). Following these practices, the Collaborative Program might consider increasing its site-scale sampling effort by intensifying the sampling at each site (Dudley et al. 2012) or by increasing the extent (length) of the sites to increase the probability of collecting rare species and to account better for habitat heterogeneity within sites (see Section 5.1). That does **not** mean that MRG site lengths should be 20 or 40 MWCWs long; however, sites that are only 200 to 400 m long seem unlikely to include all major mesohabitat types and to detect a relatively rare species in a river that is 30 to 200 m wide. Therefore, a sampling effort study is recommended to determine the degree to which longer site lengths and intensified effort at a site are warranted.

4.0 Population Monitoring Workgroup Question 3

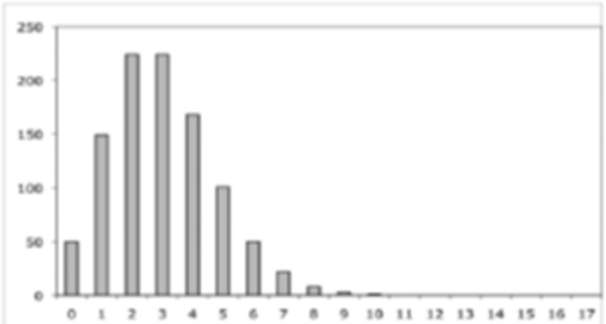
3A. Are the statistical analyses used in the Monitoring Program appropriate and in line with data distributions and characteristics?

In general, the mixture model approach currently used in the Monitoring Program to analyze the catch data is appropriate given the distribution of the data and the characteristics of those data. However, as pointed out above, improvements are needed in the manner in which data are handled (e.g., zero observations from dry sample sites, catches from multiple gears) prior to statistical analysis with mixture models.

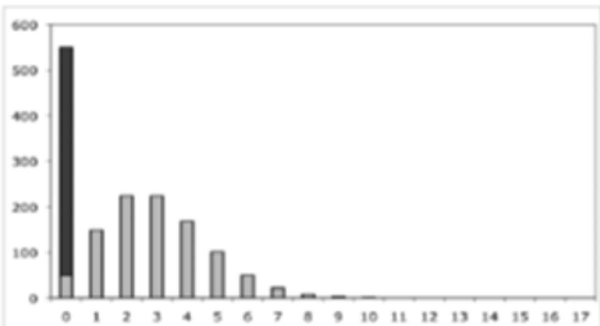
4.1 Mixture models and estimation of the CPUE index

The Monitoring Program provides nearly monthly catch data from which CPUE of the RGSM may be computed. Like many other fish monitoring programs, the catch data often contain many zeros (i.e., instances where sampling effort yields no fish). Some of the zero catches are true zeros (e.g., when RGSM are not present in the sampling area), but some of the zero catches may reflect less-than-perfect detection, that is, fish are present but are not observed (MacKenzie et al. 2006; see Section 2.4). Detectability of stream fishes using a seine (or any gear) can be highly variable and depends on features of the environment, consistency of protocols, and true abundance of the species (Williams & Fabrizio 2011; see Section 2.9). Regardless of the source of zeros, their presence results in a distribution that is not normal. Thus, standard statistical methods that assume normality of the catch data cannot be used, and instead, methods that can handle excess zeros must be applied (Martin et al. 2005).

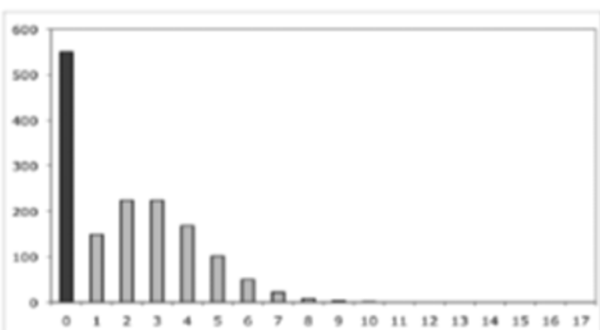
Several statistical techniques can be used to analyze count data with excess zeros, including: (1) mixture models (e.g., zero-inflated generalized linear models), and (2) hurdle or two-part models (Zuur et al. 2009). Mixture models acknowledge that zeros can arise from two processes – a binomial process and the count process. Figure 2b illustrates a zero-inflated Poisson distribution, that is, a distribution which is a mixture of a distribution at zero (dark bar) and a Poisson distribution that includes both zeros and non-zeros (gray bars; compare with Figure 2a). The negative binomial distribution may also be used to describe the count process. In the zero-inflated Poisson (or zero-inflated negative binomial), an additional process generates the extra zeros beyond those of the regular Poisson (or negative binomial) distribution. This approach differs from that of hurdle or two-part models (also known as zero-altered models). Hurdle models assume that the process that generates the zeros is not necessarily the same process that generates the non-zero observations. For example, the Poisson hurdle model is a mixture of a distribution at zero and a *truncated* Poisson distribution (i.e., a Poisson distribution with no zeros; compare Figure 2c with 2a).



a) Data appropriate for Poisson model (n=1000, Mean=3, Variance=3)



b) Data appropriate for Zero-Inflated Poisson model (n=1500, with 500 "structural" and 50 "sampling" zeros)



c) Data appropriate for Poisson Hurdle model (n=1500, with 550 "structural" and no "sampling" zeros)

Figure 2. Data appropriate for alternative Poisson models (from Hu et al. 2011). Two types of zeros are illustrated here: the gray bars represent the 'sampling' zeros and the black bars represent 'structural' zeros. In the zero-inflated model (panel b), structural zeros arise from processes assumed to generate more zeros than expected (compare panels a and b); in the hurdle model, all the zeros are structural zeros (compare panels a and c).

When applied to continuous data with excess zeros, such as CPUE data, hurdle models have been called two-stage or delta models (Lo et al. 1992; Ortiz et al. 2000; Li et al. 2015; Buchheister and Latour 2016). The delta models comprise a binomial process (which generates zeros and non-zeros), and another process that generates the zero-truncated CPUE data. Typically, the zero-truncated CPUE data are modeled with a lognormal distribution (the delta-lognormal model), but other continuous distributions are possible (e.g., a gamma distribution).

The mixture models used by the population Monitoring Program (Dudley et al. 2015), which appear to be delta-lognormal models (i.e., hurdle models in the terminology of Zuur et al. 2009), are used appropriately to estimate means and variances of the CPUE data. As noted above, these hurdle models comprise two components – one that describes the probability of observing a zero CPUE (the binomial portion), and the second that describes the probability of observing a non-zero CPUE (the lognormal portion). The mean catch is estimated as a product of the binomial and the lognormal portions. Although there appears to be added complexity with this model (two distributions are needed to model the CPUE data), the decomposition of the CPUE data into its two components provides additional information concerning the status of the RGSM. For example, the proportion of zero catches may increase (i.e., some habitats no longer support RGSM), but the CPUE of RGSM may remain constant in habitats where they occur. This scenario may result in an overall decline in the mean CPUE of fish using standard methods of estimating CPUE. Ignoring information about the proportion of zero catches, one might assume that abundance was declining similarly throughout the sampling domain, when this was not the case. The mixture models of the population Monitoring Program allow explicit investigation of these changes. Although these models appear well suited to the treatment of the CPUE data for RGSM, alternative statistical techniques (such as the application of zero-inflated negative binomial models to the discrete catch data, or the mixture-distribution method for schooling fish described by Thorson et al. 2012) may be evaluated and their behavior compared with results obtained from mixture models to better document the appropriateness of currently-used models.

4.2 Flexibility of mixture models

The Population Monitoring Program uses mixture models that consider the variability associated with mesohabitats and annual fluctuations; as such, the resulting CPUE estimates are improved. Mixture models are flexible and may incorporate design-based elements such as stratification or grouping to allow for estimation of CPUE at spatial scales of interest. Although the Monitoring Program does not use a strictly stratified design, samples are taken from multiple mesohabitats that represent available habitats in the MRG. Using data from the Monitoring Program, mixture models can be used to compute estimates of the mean and variance of the CPUE from each of the major mesohabitats (i.e., shoreline runs, shoreline pools, backwaters, pools, and riffles), from slower water versus faster water mesohabitats, and from year to year. This approach allows for comparison of mesohabitat-specific CPUEs; for example, the 2015 CPUE estimate of RGSM in shoreline runs can be compared with the 2015 CPUE estimate of RGSM in backwater habitats. Mesohabitat-specific estimates of CPUE are critical to understanding habitat use and potential changes in habitat use over time. Similarly, mean CPUEs estimated for the entire MRG may be compared between consecutive years to determine the presence and direction of annual changes in the RGSM population as a function of environmental conditions (see Section 4.3).

4.3 Mixture models and the effect of covariates on CPUE estimates

Application of mixture models allows exploration of the relationship between covariates and the probability of occurrence (derived from the binomial portion of the mixture), and between covariates and the mean of the non-zero catches (derived from the lognormal portion of the mixture). These relationships are depicted in Figures 8 and 9 in Dudley et al. (2015) and include multiple hydrological covariates such as the number of days when discharge between March and October was below 200 cfs, and the number of days from May to June that discharge exceeded 1,000 cfs. Mean annual CPUEs from 1993 to 2014 clearly depict strong relationships between the probability of RGSM occurring at a site and various hydrological covariates considered (although not all relationships were linear; Figure 8, Dudley et al. 2015). Similarly, relationships were observed between the mean of the non-zero CPUEs and various hydrological covariates that gauge river flow regime (e.g., intensity and duration; Figure 9, Dudley et al. 2015). Use of the mixture model allowed investigation of the effect of hydrological covariates on the presence of RGSM in the river and on the CPUE of these fish. We conclude that mixture models represent a positive step forward that is more informative than previous approaches.

We recommend depiction of the relationship of hydrological covariates and estimates of the mean annual CPUE for RGSM derived from mixture models (i.e., the product of δ, the probability of occurrence, and μ, the mean of the non-zero catches). Those relationships should use the October data from 1993 to 2014. Further, we recommend that such analyses be repeated for catch data collected in 2006 to the present, but using the individual seine-haul approach (rather than using the pooled-catch approach used by the Population Monitoring Program) to estimate CPUE (see Section 4.10).

4.4 Classification of mesohabitat types

In Dudley et al. (2015), catch data were analyzed at the level of five mesohabitats: shoreline runs, shoreline pools, backwaters, pools, and riffles. Further delineation of these mesohabitats (e.g., main vs secondary channels; Table 4 in Dudley et al. 2015) is not likely to provide additional insight. Analyses and consideration of the mean CPUE indices for individual mesohabitat types are, however, informative. Although the magnitude of the mean CPUE varied among mesohabitats (i.e., higher CPUEs were observed in backwaters, whereas lower CPUEs were observed in runs), consistent annual patterns in relative abundance among the five mesohabitats were observed (Figure 11, Dudley et al. 2015). This suggests that samples from any one of these mesohabitats provide a reasonable indication of overall temporal patterns in relative abundance (i.e., CPUE) of the RGSM population in the MRG. We do not recommend abandonment of the current sampling plan; however, an ancillary survey design that targets slow water mesohabitat types and more sites would be more likely to detect RGSM (see Sections 3.1, 3.3, and 5.1).

4.5 Key drivers of mesohabitat variability

Mesohabitat designations are used to differentiate portions of the sampling site with relatively homogeneous physical habitat structure conditions. Three important differentiating factors of mesohabitat type are current velocity, depth, and substrate size. Within a given mesohabitat, current velocity can be highly variable and obtaining measures of velocity within each sampled mesohabitat may be time consuming. However, other easily measured covariates may serve as proxies for water velocity, such as substrate composition and grain size. The usefulness of these proxies as measures of mesohabitat variability may be assessed by examining estimates of mesohabitat-specific velocity and substrate from a broad range of discharge conditions (which may occur in the same year), followed by model development to evaluate the performance of proxy measures. Replacement of the mesohabitat factor in the mixture model with suitable proxies of water velocity may help to improve the precision of CPUE estimates at the site level. We recommend consideration of these physical factors directly in the models to better understand the relationship between proxies of current velocity and the occurrence and abundance of RGSM at a site.

Discharge is a key driver of mesohabitat variability and as such, annual changes in discharge will affect availability and suitability of mesohabitats for the RGSM. Annual and long-term changes in CPUE may be related to annual changes in discharge, and examination of this relationship may provide insights on the response of RGSM populations to physical conditions in the river. Another potentially useful investigation is to examine the historical availability of mesohabitats in the MRG relative to discharge. If these two measures can be linked, then annual discharge may provide a good surrogate of mesohabitat availability in the MRG. The availability of mesohabitats during certain times of the year may be indicative of the potential of the system to support reproduction and recruitment of RGSM. The long-term CPUE data can be examined in light of this to determine mesohabitat availability or discharge conditions that lead to high and low recruitment years.

4.6 Relationship of hydrological variables to mean CPUE

The linear regression analysis of the effect of hydrological variables on mean CPUE in October has identified several predictors that are expressed as thresholds (e.g., the number of days that flow exceeded a given value; Figures 8 & 9 from Dudley et al. 2015). This analysis can be repeated using recalculated CPUE estimates that follow the recommendations in this report. Relating the recalculated CPUE estimates to hydrological thresholds is, however, an exploratory approach and we caution that the probabilities (i.e., P values) should not be mistaken for indications of the relative strength of the relationships. We recommend that threshold discharge values be related to the availability of mesohabitats (e.g., number of backwater habitats or number of acres of inundated floodplain) so that a better understanding of the significance of the threshold can be obtained. Another suggestion is to use a threshold discharge that reflects a historic average for the period when RGSM was present and abundant in the system. Two models are available (FLOW2D and a hydrological model; M. Porter, as communicated in Appendix F, page 21) that may allow estimation of the number of days of floodplain inundation. These models can be run retrospectively back to 1990. This type of analysis could build a better understanding of the habitat conditions necessary for the persistence and successful annual in-stream reproduction of RGSM. For example, joint consideration of the hydrograph provided to the panel (Appendix G, Written Record 03) and the time series of occurrence and relative abundance of RGSM may provide insights on minimal or necessary conditions for persistence of the species. This type of investigation is useful in predicting the response of the RGSM population in the MRG to future changes in hydrological characteristics of the river.

4.7 Detection of RGSM in seines

Factors influencing detection of RGSM in seines need to be determined and incorporated into the sampling design to permit more robust estimation of CPUE from the Monitoring Program. One of the key assumptions of typical fishery surveys is that individuals present in the study area and available to the gear are detected perfectly, that is, detection is 100%. However, this assumption is commonly untested, although recently fishery scientists have begun to address this issue (e.g., Hayer and Irwin 2008; Peoples and Frimpong 2011; Haynes et al. 2013; Hefley et al. 2013; Beesley et al. 2014). For example, in mid-Atlantic tidal rivers, the detectability of juvenile fishes in beach seines is affected by fish size; high detection rates were obtained for small fish in tidal rivers, but larger juveniles effectively avoided the gear and had detection probabilities less than 0.5 (Williams and Fabrizio 2011). In that case, detectability is maximized by sampling earlier in the season when smaller fish are present (Williams and Fabrizio 2011). Thus, such information can be used to modify sampling designs to improve estimates of CPUE. Perhaps more importantly, detectability may not be constant and may be associated with large-scale changes in the system that alter the manner in which fish interact with the sampling gear. This has important implications for long-term monitoring programs. For example, trawl-based catch rates of the endangered Delta Smelt declined through time in the Sacramento-San Joaquin River system, but catchability of the Delta Smelt has also declined as water clarity in the system has improved (Latour 2016). This raises the question: do catch rates reflect relative abundance of the Delta Smelt (which assumes constant catchability), or do catch rates reflect changes in catchability (assumes constant abundance)? Both processes are likely occurring simultaneously and thus may be confounded, but without careful study and consideration of the factors affecting detectability, inferences about the status of the species may be biased. In the MRG, lower discharges may be accompanied by lower turbidity, which may in turn, affect detection rates for RGSM. Such factors warrant further study.

3 B. Are there additional analytical techniques that could be utilized that would improve the use of CPUE?

Additional analytical techniques may be explored, but it is unclear if such approaches would reduce bias or improve precision of CPUE estimates. Comparative analyses or simulation studies are needed to ascertain if analytical improvements can be obtained or the possible magnitude of improvements.

4.8 Use of the lognormal distribution to describe non-zero catches

In mixture models, the distribution of the non-zero catches of RGSM is treated as a lognormal distribution. This is consistent with common usage in fisheries assessments and modeling, and the lognormal distribution is generally a good descriptor of the CPUE data. However, the assumption that the non-zero CPUEs follow a lognormal distribution is an important assumption that should be checked (Myers and Pepin 1990). This can be readily accomplished by evaluating the fit of the lognormal distribution to the nonzero CPUE data against that of other distributions (e.g., normal, gamma). An alternative would be to model the non-zero catches as discrete data (where CPUE is treated as an integer) using, for example, either the Poisson or negative binomial distribution. These distributions are typically used to model count data (integer data) and are appropriate for organisms that are randomly dispersed throughout the sampling domain (Poisson) or for organisms with clumped distributions (negative binomial). The lognormal distribution, however, appears more appropriate for data such as CPUE, which are not strictly integer (discrete) data (see Section 4.10).

4.9 Mixture model assumptions

The assumptions of the mixture models need to be fully defined and explored. To promote better understanding of the outcome from mixture models, we recommend examination of the assumptions underlying mixture models. Interpretation of the results from mixture models should be presented in light of the assumptions and inferences properly constrained. These assumptions include but are not limited to: (1) the CPUE data follow a lognormal distribution (see Section 4.8); (2) processes believed to generate the zero observations (including detection error and catchability issues); (3) random sampling occurs at each site and along the river; (4) seine hauls provide representative samples (see Sections 2.2 – 2.10); and (5) the treatment is replicated (here, treatment refers to year, but may refer to other factors). With regard to assumption 3, several studies provide evidence to support the use of fixed-station sites for monitoring temporal trends in abundance (e.g., Quist et al. 2006; Tuckey and Fabrizio 2013; Li et al. 2015; Archdeacon et al. 2015)—but see discussion of naughty naughts in Sections 2.5, 3.3, and 4.12. The remaining assumptions should be addressed.

4.10 Estimation of mean site-specific CPUE

Because each seine haul has a different length and therefore, yields a different estimate of the area sampled, CPUE estimates cannot be treated as integers. Instead, the distribution of the CPUE data is treated as a continuous variable (specifically, lognormal). The length of the seine haul and hence, area sampled, varies: the small-mesh seine is used to sample primarily juvenile RGSM and the fine-mesh seine is used to sample primarily larval fish (Dudley et al. 2015, see Section 2.3 for additional detail). In months when larvae and juveniles co-occur, CPUE is computed by summing larval and juvenile RGSM captured at a site and dividing this sum by the total effort (number of square meters sampled) expended at the site with both types of seines (Dudley et al. 2015). The assumptions inherent in this approach are unstated but include equal catchability of RGSM by the two kinds of seines (see Section 2.7), and consistent sampling effort among sites, that is, the proportional allocation of sampling effort among mesohabitats (i.e., shoreline runs, shoreline pools, backwaters, pools, and riffles) is constant from site to site. However, these assumptions are unlikely to hold. First, catchability, though unknown, is not equal for the two size classes or the two gears. Second, a variable number of mesohabitat types are sampled at any given site. In addition, “mesohabitats are not sampled in proportion to their availability” (p. 33, Dudley et al. 2015). In particular, backwaters, when present, are sampled twice, even though they are relatively rare in the MRG. When site-specific effort among mesohabitat types varies, then mean site-specific CPUE estimates based on pooling (Dudley et al. 2015 method) and those based on individual hauls will differ and will depend on the proportional sampling among mesohabitat types (see Section 2.8). In general, the direction of the bias in the mean CPUE depends on fish density in each mesohabitat such that mean CPUE will be underestimated at sites where a greater proportion of the effort yields a smaller proportion of the fish, and overestimated at sites where a greater proportion of the effort yields a greater proportion of fish. We therefore recommend estimation of mean site-specific CPUE from individual seine hauls (which are distinguishable in the database as of 2006). Mean CPUE at each site is computed from the individual CPUEs from each of the 18-20 mesohabitats (i.e., up to five different types) sampled per site. An approach similar to stratification may be applied whereby the mean site CPUE is a weighted estimate of mean CPUE at individual mesohabitats and weights are based on the proportion of the site comprised by each mesohabitat and the effort expended per mesohabitat. Using data from 2006 to the present, the direction and magnitude of the bias associated with pooling can be explored. Although re-estimation of site-specific CPUEs is not likely to lead to order-of-magnitude changes in the estimates of annual CPUE for the MRG, increasing the accuracy of the CPUE estimates should be a goal of the Monitoring Program.

4.11 Zero catches

Another aspect of the CPUE data that warrants further consideration is the treatment of zero catches (see Section 2.4). Aside from the naughty naughts, which were discussed earlier (Sections 2.5, 3.2, and 3.3), two types of zero observations may occur in surveys: true and false zeros. True zeros, also known as structural zeros, may arise due to chance (RGSM may be temporarily absent from the sampling site) or because the frequency of occurrence of RGSM is low (some sampling sites are not occupied by RGSM even though the habitat is suitable) (Martin et al. 2005). In contrast, false zeros arise from survey design error (e.g., sites are sampled when no RGSM are present, but at other times, RGSM may occupy the site), sampling error (e.g., the type of gear is not effective at capturing RGSM when they are present), or observer error (e.g., RGSM occupy the site, but observers misidentify the species). Survey designs and methods should strive to eliminate or at least, minimize false zeros. Because of the near-monthly frequency of sampling, the standardized use of seines, and the execution of the sampling by trained observers, the Population Monitoring Program appears to minimize the occurrence of false zeros.

Both true and false zeros should be included in CPUE computations (and the Population Monitoring Program currently does so). However, the naughty naughts associated with dry sites must be removed from calculations of annual mean CPUE (Zuur et al. 2009).

Fortunately, it is not necessary for the analyst to distinguish between true and false zeros when using mixture models or zero-inflated models, which specifically address the presence of these zeros in the data (Martin et al. 2005). The occurrence of zeros in the data leads to zero-inflation when the frequency of the occurrence of zero catches exceeds the expected frequency of the (assumed) underlying distribution. This has implications for protocols implemented in the Monitoring Program when larval fish are difficult to detect.

4.12 Alternatives to mixture models

Alternatives to the parametric mixture model, in particular, Bayesian hierarchical models, also may be considered for estimation of annual CPUEs. Bayesian hierarchical models are increasingly used by fisheries scientists to better understand how covariate effects are manifested at multiple scales (multiple hierarchies; e.g., Beesley et al. 2014). These approaches are particularly suitable for exploration of abundance of uncommon or rare species such as the RGSM, because Bayesian methods can borrow information from common species to inform relationships for less common species. For example, a hierarchical Bayesian mixture model may be constructed for RGSM and other species to consider the effects of flow on the presence (binomial portion) as well as on the CPUE (lognormal portion) of RGSM. A hierarchical approach can be used to examine spatial effects (e.g., at the reach level) and as such, would provide a means to address the question of river-wide and reach-wide processes that influence CPUE. This approach was recently developed for estimating abundance of an invasive species in tidal tributaries of Chesapeake Bay (Tang et al. *in review*). However, it is not clear that application of Bayesian models to RGSM catch data would provide additional insights on the dynamics of RGSM populations.

4.13. Alternatives for exploring relationships between CPUE and covariates

Other analytical approaches such as classification and regression trees (CART; Breiman et al. 1984), boosted regression trees (Friedman et al. 2000; Friedman 2001), or random forests (Breiman 2001) may be used to examine relationships between hydrologic variables and CPUE to identify thresholds above or below which CPUE demonstrates changes. CART and associated techniques are nonparametric approaches for exploring relationships among the response (e.g., CPUE, presence, density) and covariates hypothesized to be important in mediating that response. As such, they have been widely applied in fisheries research (e.g., Norcross et al. 1997; Rathert et al. 1999; Olden and Jackson 2002; Leathwick et al. 2006; Froeschke et al. 2013; Miller et al. 2014; Then et al. 2015). These methods are particularly useful for identifying thresholds of response. Regression tree models require no *a priori* distributional assumptions (about the response or covariates), can handle zero data and interactions, and work well in the presence of linear or nonlinear relationships. CART and associated techniques use recursive partitioning to build trees whose leaves comprise samples that are homogeneous in terms of their mean response. In addition, the importance of covariates in developing the tree can be assessed using statistical measures. These approaches hold promise in elucidating the relationship between hydrological conditions and the CPUE, presence, or density of RGSM (e.g., Figures 8 and 9 in Dudley et al. 2015).

4.14. Defining spatial scales relevant to RGSM

Resource managers would benefit from the identification of fishery effects due to anthropogenic activities in the Middle Rio Grande; however, the spatial scale of those effects need to be clearly delineated. Although the design of the Monitoring Program in the MRG was optimized to provide insight on the status and trends of the RGSM population, enhanced understanding of the response of the population to changes in river discharge and availability of mesohabitats requires directed studies that use a different sampling design. For example, the effects of water management policies may be manifested at the level of a single reach and therefore, relative abundance of RGSM must be assessed at that spatial scale (see Section 3.4). Other activities, such as habitat rehabilitation, may be more localized, for example, at the sub-reach scale, on the order of 100 to 1,000 m. Research on the effects of such alterations on the distribution and abundance of RGSM requires implementation of a sampling design that addresses the spatial scale of putative effects (e.g., Roni 2005; Thompson 2006). The design of the current Monitoring Program is not appropriate to address these questions. For example, sampling intensity in the Angostura Reach (n = 5 sites) is unlikely sufficient to provide a reliable estimate of relative abundance of RGSM in response to habitat modifications or flow alterations affecting only this reach (see Sections 3.3 and 3.4). The spatial area in which the response is measured must be properly constrained so that the effects of a particular alteration can be measured; this is a fundamental lesson applicable to a wide range of natural resource conservation questions (Creel et al. 2015). The Population Estimation Program, which uses repeated sampling appropriate for occupancy modeling, has provided additional insight on persistence, colonization, and extinction. This approach should be continued, but it is noted that such sampling is in addition to the current Monitoring Program.

5.0 Population Monitoring Workgroup Question 4

4. What revisions can be made to the sampling design to improve accuracy, precision, and power to detect change in RGSM abundance?

Although a revision should not be implemented without strong empirical evidence that an alternative sampling design and method provide more accurate and precise estimates of CPUE, the expert panelists feel that several possible revisions could further strengthen the program.

5.1. Sampling design

The Monitoring Program could be improved by increasing site lengths (Cao et al. 2001; Hughes et al. 2002; Kanno et al. 2009), effort per site (Dudley et al. 2012) or number of sites (Smith & Jones 2005; Olsen & Peck 2008; Anlauf et al. 2011; Larsen et al. 2012). This enhanced sampling effort would likely increase the capture of RGSM over the MRG and enable better understanding of the relative abundance and distribution of this species that is purported to have a highly clumped (patchy) spatial distribution. The Monitoring Program also could be improved by conducting a rigorous population estimation program (Widmer et al. 2010; Dudley et al. 2012), and by implementing a sampling design that facilitates occupancy modeling (Dudley et al. 2012) in addition to the existing population monitoring sampling in October. For example, Widmer et al. (2010) reported that single-pass sampling in the Pecos River detected significantly fewer species of both age-0 and age-1 small-bodied fishes than did multi-pass sampling. The relative effects of increased sampling effort on estimates of RGSM CPUE, and occupancy can be evaluated through use of existing data to determine the major sources of variance (see Figure 1), but a far more rigorous and convincing approach would entail pilot studies (e.g., Fischer & Paukert 2000; Cao et al. 2001; Hughes et al. 2002; Smith & Jones 2005; Dudley et al. 2012).

The Monitoring Program's sampling design currently involves sampling at 20, 200-meter-long, fixed sites selected from approximately 1,100 possible 200-meter-long sites over the length of MRG. It is assumed that the 20 sites are representative of sites over the length of the MRG, but the sites were not randomly selected. Mean CPUE over the 20 sites is used as an index of relative abundance of RGSM to make inferences regarding the species over the length of the MRG. Some of the fixed sampling sites are dry and not sampled during some months in some years. Because no sampling effort has occurred, the lack of sampling cannot be considered as a zero CPUE value (see Sections 2.5, 3.2, 3.3, and 4.12). However, during sampling months when dry sites are encountered, both unsampled dry sites and sites with 200 m of water that were sampled are included in CPUE computation. Treating zero RGSM at dry and wetted sites in the same manner for CPUE estimation over the length of the MRG creates biased estimates because it includes both wetted sites that were sampled and dry sites that were not sampled. Consequently, mean CPUE provides a biased index of relative abundance of RGSM when discharge through the MRG declines to a level where any of the 20 sites cannot be sampled. This situation is likely to be exacerbated by climate change and increased human water demands, unless instream flows are provided for the RGSM (see Section 7). Because 20 fixed sites may underestimate or overestimate true population sizes (Hughes et al. 2000), especially in naturally changing, patchy and anthropogenically altered environments, an alternative survey design could be implemented when dry sites are encountered.

One possible approach is an inverse sample drawn from a GRTS design in which new sites are added when dry or inaccessible candidate sites are encountered, while maintaining a spatially balanced sample (Stevens & Olsen 2004; Olsen & Peck 2008; Dudley et al. 2012). The USEPA used such a sampling design in its National Wadeable Stream Assessment (Olsen & Peck 2008; Paulsen et al. 2008; USEPA 2013) by drawing a large over-sample of candidate sites for arid regions. The key to such a design is an appropriate sample frame from which to choose candidate sites (e.g., perhaps a real-time satellite photo of wetted areas of the MRG) similar to the satellite-generated wetland map used by the USEPA for its

National Wetland Condition Assessment (USEPA 2015). Real-time drone flights are another possible means of selecting sites (see Section 3.3). All 1,100 possible sites should have an equal probability of selection and selected sites that are not sampled should be documented as not assessed or insufficiently sampled, along with the reason why. Such data can be very useful for making habitat status assessments (e.g., percent of the MRG that is dry). For reasons stated in Sections 3.3 and 3.4 and assuming that the Monitoring Program would like to make population assessments of the three reaches, one possible sampling design would be based on a total sample of 60 to 150 randomly selected sites per year (20 to 50 per reach) each October. Each site would remain 200 m long and seined for 100 m with small-mesh seines and 100 m with fine-mesh seines (Bonar et al. 2009; Bidlack et al. 2014). Individual haul lengths should be limited to the size of major mesohabitat units or some multiple of the seine length depending on site conditions. Sampling should be focused on shallow (<20 cm to 40 cm) silt and sand (low current velocity) habitats. Repeating the hauls on the same day and on subsequent days would allow estimates of population size and occupancy, respectively (Dudley 2012). Taking water samples at each site for environmental DNA (eDNA) of RGSM could provide another indicator of RGSM presence in the system (but not abundance). This technique employs the presence and detection of shed cells to indicate the presence of otherwise rarely encountered species (Takahara et al. 2012; Simmons et al. 2016). Although multiple issues remain regarding detection probability, water sample volume, DNA shedding rate, and biomass and temperature effects, the Monitoring Program would be wise to follow the development of the eDNA approach and its potential application in RGSM monitoring.

5.2. Population biology

Additional studies on catchability factors, stock-recruitment, fecundity, survival, and population genetics and epigenetics would be useful because they affect RGSM population monitoring, estimation, occupancy, and viability to varying degrees.

As discussed in Sections 2 and 4, further studies of factors affecting catchability could lead to changes in the covariates measured during sampling (or independently), the analytical method used for estimating CPUE, and the sampling methodology itself (Arreguín-Sánchez 1996; Wilberg et al. 2010; Benejam et al. 2012; NEON 2014). For example, how do mesohabitat type, velocity, depth, water temperature, substrate, and fish cover at existing sites affect catchability (e.g., USFWS 2010)? How do other mesohabitat types (e.g., other low velocity habitats, off-channel pools, wetted floodplains) and sampling gears (e.g. bag/beach seines versus minnow seines) alter catchability (Bonar et al. 2009; NEON 2014)? How do RGSM size (length) and numbers affect catchability? If the suggested changes in survey design were implemented, a substantial additional source of variability in catchability could result from the markedly greater number of crews needed to sample the greater number of sites in a more intensive manner (i.e., crew variability), but see Archdeacon et al. (2015) and USEPA (2013) on training to reduce crew variability.

Stock-recruitment studies would be useful for evaluating the abundance of fall recruits relative to spring spawner abundance, spring and summer flows (Weber & Brown 2013), and hatchery practices (Quiñones et al. 2014; Carmichael et al. 2015). Although such studies are difficult for an r-selected species such as the RGSM, determining the degree to which spawner abundance versus environmental factors affects recruits could improve conservation and management of the RGSM as it has for other valued species (e.g., Fleischman et al. 2013; Singh et al. 2014; Zimmerman et al. 2015). Recruitment in some fish populations has been shown to be density dependent (i.e., recruitment dependent on the number of spawners), density independent (i.e., recruitment driven mostly by environmental conditions), or varying between the two depending on the level of environmental pressures and a threshold number of spawners. For example, to what degree is RGSM recruitment limited by the number of spawning fish, proportion of hatchery fish, and the flow regime at the times of spawning, rearing, and over-wintering?

A study of age-specific fecundity and survival rates based on pre-breeding (fall) population estimates would be useful for documenting population recovery and extirpation potentials as a function of press disturbances such as altered flow regimes (e.g., Schaaf et al. 1987; Lo et al. 1995: Paulsen et al. 2007). Typically, older, larger females produce more eggs and spawn in more suitable habitats than smaller fish. A shift to a relatively large proportion of age-0 fish in the October catch could suggest a shift to a less reproductively fit population. The effects of this on the overall population fitness level would be worthy of further investigation.

5.3. Improved collaboration among Collaborative Program elements

The current Collaborative Program provides a foundation for improved collaboration among MRG interests that could further improve accuracy, precision, and power to detect change in RGSM abundance in several ways.

Standardized sampling, data sharing, and analytical methods across agencies with RGSM interests could increase the sample size, reduce gross costs, and improve trust among groups with conflicting interests. Such a process has improved relationships among state and federal environmental protection agencies in the USA (e.g., Paulsen et al. 2008; Hughes & Peck 2008; Mulvey et al. 2009) and the European Union (e.g., Pont et al. 2006; Schmutz et al. 2007). For example, because they used the same Environmental Monitoring and Assessment Program (EMAP) protocol, Mulvey et al. (2009) were able to analyze data from 10 studies (6 agencies, 450 randomly selected sites) to assess ecological conditions in Oregon's Willamette River Basin. Pont et al. (2006) were able to assess fish assemblage condition across twelve European nations (5,252 sites) because fishery biologists in each nation used the same European standard sampling protocol.

There is considerable potential for further data use by the Collaborative Program in management decisions (Stephens 2015) and recovery actions (Cowley 2006; USFWS 2010). In a recent survey of the Executive Committee of the Collaborative Program regarding the Monitoring Program (Stephens 2015), at least seven monitoring questions were deemed as having a critical or important need, but survey respondents felt that the Monitoring Program had inadequately met those needs for various reasons. It would be very useful for the Collaborative Program partners to determine explicitly the changes needed to provide greater confidence in the data produced by the Monitoring Program.

The existing population monitoring data and the RGSM recovery criteria (USFWS 2010), together with appropriate adjustments developed from this and other evaluations, plus current and future research, could be used to establish quantitative objectives for adaptive management planning and implementation (Runge 2011; Rist 2012; Conroy & Peterson 2013). Such an improved or parallel monitoring program should be designed to be robust enough to assess the effects of large-scale management actions on RGSM at the reach or MRG scale in dry and wet years. Admittedly, the parallel or ancillary monitoring program would be much more costly than the current program, and perhaps for that reason alone, the lead monitoring scientists should become partners in the Collaborative Program and the RIP rather than be viewed as outside consultants. Adaptive management employs a rigorous decision making process (Conroy and Peterson 2013) or a deliberately experimental approach (Walters 1986) to increase knowledge and decrease the uncertainty of management results. Both approaches require rigorous monitoring, such as that employed in the Monitoring Program. However, adaptive management has become an agency buzzword with management plans that are more trial-and-error approaches than deliberate, monitored actions designed to improve resource management. Therefore, effective adaptive management plans must explicitly identify current knowledge and key uncertainties, articulate management expectations clearly, design and implement targeted monitoring programs to gain knowledge useful for reducing those key uncertainties, improve predictive models with continued monitoring information, and modify management decisions based on the new knowledge (Runge 2011). Plans also must clearly state what will and will not occur (and when such actions will occur) when pre-identified trigger points are reached (Nie and Schulz 2012). Improved management is accomplished only if the new knowledge is used to reevaluate management decisions, resolve ambiguities, and alter future management decisions as needed. Those subsequent management decisions are then monitored and the cycle continues—ideally leading to ever-improved resource management. For recent examples of an adaptive management program with a fish and fish habitat focus, see Bennett et al. (2016).

6.0 Recommendations

This section summarizes recommendations discussed in this report and during the December workshop. Some of the Expert Panelists' suggestions can be easily implemented at little cost; other suggestions will require additional pilot studies, research, or analyses based on existing data. A key consideration in determining priorities among our many suggestions is to focus changes on those that are most likely to reduce false zero CPUE estimates, naughty naughts, and the variance in CPUE estimates at the reach- and MRG-scale. Such changes should increase the confidence in those estimates among all the partners of the Collaborative Program.

6.1 CPUE computation

(1) Separate the catch and effort data from the small-mesh seine and the fine-mesh seine into two data sets and compute separate CPUE indices for each gear type, as well as for individual age classes captured in each gear type

(2) The CPUE from the small-mesh seine is primarily an index of the relative abundance of a single cohort of RGSM (i.e., the most recent cohort) that is recruited into the gear late in the summer and captured into the summer of the following year. The precision of the index can be improved by exclusion of older cohorts. A separate CPUE index can be computed for older cohorts. Consider the use of length-at-age data and frequency histograms to identify cohorts.

(3) Only larval fish should be included in the computation of CPUE indices from the fine-mesh seine because of this gear's selectivity for this life stage.

(4) An aspect of the CPUE data that warrants attention is the treatment of zero catches in data analyses. Inclusion of dry sample sites as zero CPUE values when analyzing CPUE data for RGSM in the MRG should be avoided. Field data records and the database in which the RGSM CPUE data are stored allow dry sampling sites to be distinguished from sites that were sampled and no RGSM were caught. The problem arises during statistical analyses because the naughty naughts (observations of zeros at dry sampling sites) are treated in the same manner as the zero catches at fished sites where no RGSM are caught.

(5) Survey designs should strive to minimize false zeros resulting from: (1) an inappropriate sampling design (e.g., sampling in mesohabitats avoided by RGSM) and (2) ineffective survey methods (e.g., insufficient sampling effort to detect an organism when it is present).

(6) The proportions of various mesohabitat types sampled are likely to bias CPUE indices because the catchability coefficient probably differs among mesohabitat types and RGSM are likely to be selective for specific mesohabitat types. We recommend that better understanding of the influence of mesohabitat type on CPUE be developed and used to account for variability in CPUE indices. Further, we recommend that estimation of mean site-specific CPUE be improved by addressing the variable number of mesohabitats that are sampled at any given site and the amount of sampling in each mesohabitat type. We recommend estimation of mean site-specific CPUE from individual seine hauls (which are distinguishable in the database as of 2006); mean CPUE at each site is then computed from the individual CPUEs at each of the 18-20 mesohabitat units sampled per site.

(7) Environmental factors (e.g., turbidity, water temperature, substrate size, depth, current velocity, and discharge) during sampling are likely to bias CPUE indices because of their influence on catchability. We recommend that better understanding of the influence of measurable environmental factors on the catchability of each seine type be developed and used to account for variability in CPUE indices.

(8) Factors influencing detection and catchability of RGSM in seines need to be determined and incorporated into the sampling design to permit more robust estimation of CPUE.

(9) Measures of CPUE for RGSM from the MRG are currently identified as recovery standards for the species. We recommend modification of recovery standards to be explicit regarding the gear, sampling design, sampling techniques, data analysis, and life stage, as well as protocols used to compute the CPUE index.

(10) We recommend depiction of the relationship of hydrological covariates and estimates of the mean annual CPUE for RGSM derived from the mixture model. Those relationships should use the October data from 1993 to 2014. Further, we recommend that such analyses be repeated for catch data collected in 2006 to the present, but using the individual seine-haul approach to estimate CPUE.

(11) We recommend that the assumptions of the mixture models be fully defined and that the results of analyses be interpreted with consideration of the assumptions and the effects of the potential violation of assumptions.

6.2 Survey design

(12) A greater number of sampling sites would improve the accuracy and precision of status assessments and improve estimates of RGSM CPUE and spatial distribution, especially at the reach scale. A greater number of sampling sites in each of the three reaches would facilitate status and trend estimates at the reach scale. To make statistically rigorous reach-scale CPUE estimates, 20-50 sites per reach are recommended. A design with substantially more sites and longer site lengths should be more effective at detecting RGSM when they are at low densities or demonstrating patchy distributions.

(13) When river flows decline so that dry sampling sites occur among the 20 fixed sites sampled by the Monitoring Program, the ability to make inference regarding CPUE of RGSM over the MRG is impaired. The current 20-fixed-site sampling is not adequate when dry sampling sites occur. An ancillary randomized sampling design is recommended at such times to be able to make inferences about RGSM abundance and distribution throughout the entire MRG. Such a random sampling design would entail sampling at many more sites over the length of the MRG. An ancillary design of this type would enhance the feasibility of assessing the abundance and distribution of RGSM in the MRG during years of low flows and when the species is likely to occur in low abundance.

6.3 Future research

(14) Consider using key drivers of mesohabitat variability, such as current velocity, substrate size, and water depth at specific locations where seines are deployed, to replace the mesohabitat factor in the mixture models.

(16) Examine the historical availability of mesohabitats in the MRG relative to discharge. If these two measures can be linked, then annual or monthly discharge may provide a good surrogate of mesohabitat availability.

(17) Evaluate alternatives to the parametric mixture model, in particular, Bayesian hierarchical models, for estimating annual CPUEs.

(18) Use classification and regression trees, boosted regression trees, or random forests to examine relationships between hydrologic variables and CPUE for identifying thresholds above or below which CPUE exhibits changes.

(19) Implement directed studies using different sampling designs, such as multi-year, multi-site, before-after-control-impact (BACI) designs to enhance understanding of the response of the population to changes in river discharge, habitat rehabilitation projects, and availability of mesohabitats.

(21) Conduct stock-recruitment studies to determine how the abundance of fall recruits relates to the abundance of spring spawners. Investigate the effects of spring and summer discharges on the stock-recruitment relationship to enhance understanding of the dynamics of RGSM. Implement a spring sampling protocol at spawning sites to estimate the number of spring spawners, and compare with October results for several years; such studies may provide useful data on RGSM population dynamics and limiting factors.

(22) Complete a study of age-specific fecundity and survival rates based on pre-breeding (fall) population estimates, spring spawners, and hatchery supplementation. Results from this study could be used to estimate population recovery and extirpation potentials as a function of altered flow regimes and stocking.

(23) Consider genetic fingerprinting and epigenetic studies, including bar-coding and gene-expression, of presumed wild and hatchery fish to help determine hatchery contributions to the spring spawners and the long-term risks to the wild population.

(24) Expand the analyses in Dudley et al. (2015) to assess flow regime and habitat fragmentation effects on RGSM occurrence and abundance and suggest preliminary flow regimes for rehabilitating the wild RGSM population.

7. Observations beyond the scope of the Population Monitoring Workshop

This section summarizes observations of the expert panelists on issues that were beyond the scope of the Population Monitoring Workshop. The panelists were not provided material on the topics discussed below (instream flow, climate change, hatchery practices, genetic analyses, adaptive management, etc.) and therefore, were unaware of current research efforts on these topics.

(1) Attention to long-term climate-change issues and integration with climate-change planning efforts was not evident to the expert panelists (from the readings or from discussions at the December workshop) regarding how the Cooperative Program and Monitoring Program plan to address markedly lower flows and higher water temperatures. In western North America, global warming is projected to reduce precipitation overall, resulting in widespread and persistent drought (Dai 2013; Garfin et al. 2013; Ault et al. 2014), and to shift winter precipitation from snow to rain at higher altitudes (ISAB 2007; Healey 2011; Melillo et al 2014). Increased late fall and winter rains are likely to increase fall and winter stream flows as well as the intensity and frequency of fall and winter flooding. Diminished annual snow packs will reduce the spring runoff, as well as late summer and early fall stream flows, and increase stream temperatures (Isaac et al. 2010; Garfin et al. 2013). A return to the long-term drought conditions experienced in the past is highly likely if global carbon emissions are not markedly reduced in the near future.

(2) The MRG lacks minimum instream flow requirements to assure recovery. A major element of discussion by program scientists and interested parties during the workshop focused on low-flow periods and the potential for survival of RGSM during those periods when portions of the MRG have no observed surface flows or when there is no measurable discharge at gaging stations. It became evident to the external panelists that there are no specified minimum instream flow requirements or guidelines for the MRG. Minimum instream flow requirements or guidelines would not only enhance the potential for recovery of the RGSM in the MRG, but they would enable the current 20-site design of the Monitoring Program to be used to assess continuously status and trends of the RGSM stock in the MRG.

(3) The Monitoring Program assesses relative abundance of the RGSM in October; the young-of-year fish encountered at this time are likely to include the progeny of hatchery fish that were stocked the previous year (in November), survived the winter, and successfully reproduced. As such, the Monitoring Program is measuring the ability of hatchery stocking to contribute to or maintain a population in the MRG. Understanding of the dynamics of the RGSM population and the effects of changes in water resources in the MRG is hindered by confounding of environmental and hatchery-fish effects. There is a need for Monitoring Program scientists to effectively disentangle the source of new recruits (Creel et al. 2015), in particular the relative contribution of hatchery-origin fish and naturally spawned wild fish. One suggestion is to apply individual-based models (IBMs) to simulate changes in the system (e.g., cessation of stocking, decreased discharge rates) and assess those effects on RGSM populations (see e.g., Rose et al. 2013a and b). IBMs are used to describe population outcomes by tracking the fate of the individual fish that compose the population. As such, these models allow individual fish to exhibit unique combinations of growth, survival, fecundity, and movement probabilities. Although this is a powerful approach for the study of animal populations, IBMs require large amounts of data. Thus, the feasibility of this approach will depend on the depth of knowledge of basic biological processes for RGSM in the MRG.

(4) In recent years, low RGSM abundance has led to salvaging fish from residual pools and the introduction of hatchery reared fish to supplement the RGSM population. This creates a dilemma of providing fish to preclude RGSM extinction versus creating a domesticated hatchery-dominated population ill equipped to survive the rigors of a highly stressed environment. Therefore, additional genetic fingerprinting and epigenetic studies of presumed wild, hatchery, and hatchery-originated progeny are needed to determine hatchery contributions to the spring spawners and the risks thereof to the wild population (Quiñones et al. 2014; Trushenski et al. 2015; Carmichael et al. 2015). In a study on

steelhead, Araki et al. (2008) found that hatchery spawners reduced recruitment by 2-88% depending on spawner source, sex, and years of hatchery supplementation. Evaluating two generations of steelhead that were reared in a hatchery and then bred in the wild after release, Araki et al. (2007) reported a 40% decline in reproductive capacity. Christie et al. (2016) determined that over 700 genes were differentially expressed by the first-generation offspring of wild versus hatchery steelhead, including metabolic, immunity, and healing responses. Bakke (2013) provides a synopsis of more than 50 studies of the negative effects of hatcheries on the reproductive fitness of several salmonid species. Although salmonids and cyprinids are markedly different fish with differing life histories, the genetic effects of hatcheries on wild fish may be similar or even greater on an *r*-selected species. For example, Osborne et al. (2006) reported that RGSM that had been spawned and reared in hatcheries had reduced allelic diversity and fish reared in hatcheries from wild-caught eggs had greater inbreeding coefficients compared with wild populations. Allelic richness of RGSM declined from parent to progeny regardless of whether progeny originated from monogamous mating, communal spawning induced by hormones, or communal spawning induced by environmental cues, although more viable eggs were produced in the latter case (Osborne et al. 2013). Nonetheless, Osborne et al. (2012) concluded that the genetic diversity of RGSM has been maintained for 10 years. The question of greatest concern here is the degree to which the population has become, or is becoming, a largely hatchery-derived population with reduced survivability in the face of climate change and other physical and chemical habitat alterations. This becomes of greatest concern when wild populations are naturally and anthropogenically constricted in numbers relative to the numbers of hatchery-origin fish added to the population. Because of such natural and anthropogenic pressures, the highly variable RGSM population likely will continue to be reduced and the wild population may be extirpated (Lawson 1993; Cowley 2006). Continuation of current hatchery augmentation practices should include a rigorous risk/benefit analysis.

(5) Although not explicitly discussed during the December workshop, the current recovery plan and criteria for the RGSM (USFWS 2010) are based on the 20-fixed-site sampling protocol. Recovery criteria for the MRG include presence of unmarked and age-0 RGSM at 75% of all sites per reach in October; an October CPUE of >5 RGSM/100 m^2 in all sites in a reach for five consecutive years; and age-0 RGSM in 75% of all sites in a reach for five consecutive years. To the degree that insufficient October flows limit sampling of all 20 sites, those recovery criteria cannot be met. In addition, the recovery plan implicitly assumes that genetic exchange is generally in a downstream direction, that the wild RGSM genetic composition has been preserved, and that unmarked fish have a wild genotype. However, those assumptions may be negated by ongoing hatchery practices as discussed above in Observation 4.

(6) The analyses in Dudley et al. (2015) could lead to quantitative instream flow and habitat studies and be used to assess flow regime and habitat fragmentation effects on RGSM occurrence and abundance and then used to set preliminary system-wide instream flow criteria for rehabilitating RGSM. This is because current rehabilitation actions such as salvage, stocking of hatchery fish, and local flow and physical habitat manipulations have only local or temporary effects compared with the system-wide effects of major diversion dams and basin-scale land use (e.g., Wang et al. 2003; Hughes et al. 2005, 2014). Normalizing flow regimes, improving fish passage, and extensively lowering floodplains would help rehabilitate a species such as the RGSM (Williams et al. 1999; Tockner et al. 2000; Dudley et al. 2015; Novak et al. 2015); admittedly, such rehabilitation measures may be costly. Although portions of the MRG have experienced periods of natural drying and flooding historically, anthropogenic increases in the frequency or extent of drying and anthropogenic decreases in the frequency and extent of flooding, together with passage barriers, likely reduce the potential of wild RGSM to persist and flourish in the MRG (Hughes et al. 2005; Novak et al. 2015).

(7) During the workshop, the panelists noted that a number of organizations and agencies were engaged in research on RGSM in the MRG (i.e., US Fish & Wildlife Service, Bureau of Reclamation, and Army Corps of Engineers). However, the expert panelists did not identify whether formal procedures for sharing outcomes and results from these studies are in place, for example, via annual multi-day research review and discussion meetings with all Cooperative Program and Monitoring Program partners. In addition, models to describe the hydrodynamics of the MRG have been developed, but fish population studies do not appear to make use of these models. The water resource problems in the MRG are complex and water management actions affecting discharge and flow in the river affect the population of RGSM. An annual research review or similar activity may help to strengthen information exchange and advance scientific understanding of the issues in the MRG.

(8) An adaptive management program may help to improve understanding of the relationship between management actions in the MRG and the status of the RGSM population. We understand that such an approach will soon be implemented for the MRG and encourage the Collaborative Program to pursue a rigorous adaptive management program. Adaptive management is typically viewed as a partnership between management agencies and agencies engaged in research to address critical uncertainties in the system. Partnerships are key because new knowledge about the system will be obtained only when research and management work hand-in-hand. In adaptive management, (1) the science problems must be defined in a clear manner that permits design of targeted investigations; (2) conceptual and simulation models are then used to investigate responses of the system to potential management interventions; (3) direct, purposeful manipulations are implemented and the response of the system measured in a statistically reliable manner; and (4) analyses and synthesis of outcomes are completed in a timely manner to support robust decision-making. Adaptive management in the MRG would benefit from a conceptual model of the system that integrates water use, hydrodynamics, and fish population responses. It is unclear if such a model exists, but it is imperative to develop such models to ensure that management manipulations will provide sufficient contrast and ensure a measurable result.

(9) In addition to adaptive management, Collaborative Program partners and collaborators may wish to consider other tools such as scenario planning (Baker et al. 2004; Hulse et al. 2004; Allen and Gunderson 2011; Rowland et al. 2014) and resilience building (NYC 2013; Norfolk 2014). Scenario planning may be an effective management approach when uncertainty about the system is high and factors that affect the system are not readily controlled (e.g., amount of snow pack available for replenishment of rivers). In this approach, alternative futures are explored with the goal of identifying improvements to current management actions. This may be a good strategy to pursue now, perhaps together with adaptive management. As uncertainty about the system declines (through learning derived from targeted research studies and adaptive management), we suggest implementing a resilience building approach. The approach is effective when driving factors remain uncontrollable and system uncertainty is low. Many coastal cities have adopted this approach in the face of rising sea levels (e.g., New York City [NYC 2013] and Norfolk, VA [Norfolk 2014]).

(10) The research done on the RGSM warrants publication in high-level peer reviewed journals. The Expert Panel was provided 14 documents to help it prepare for the December workshop. Of those 14, only 2 were published in, or submitted to, a peer-reviewed journal by a member of the Program; however, the results and interpretations included in the annual reports should be published in journals. Similarly, the Expert Panelists were shown agency reports at the Workshop that were not included in the preselected workshop reading materials that likely had received thorough agency review, but apparently had not yet been submitted for journal publication. In the scientific world, peer-reviewed journal

publication is the standard by which research is judged. Publishing in such journals would add increased scientific credibility to the Collaborative Program, and funding the time needed to prepare and revise journal manuscripts should be included in the research grants of the Monitoring Program.

8.0 References

Allen CR, Gunderson LH. 2011. Pathology and failure in the design and implementation of adaptive management. Journal of Environmental Management 92:1379-1384.

Angradi TR, Bolgrien DW, Jicha TM, Pearson MS, Hill BH, Taylor DL, Schweiger EW, Shepard L. Batterman AR, Moffett MF, Elonen CM, Anderson LE. 2009. A bioassessment approach for mid-continent great rivers: the Upper Mississippi, Missouri, and Ohio (USA). Environmental Monitoring and Assessment 152: 425-442.

Anlauf KJ, Gaeuman W, Jones KK. 2011. Detection of regional trends in salmonid habitat in coastal streams, Oregon. Transactions of the American Fisheries Society 140:52-66.

Archdeacon TP, Henderson KR, Austring TJ, Cook RL. 2015. Comparison of fish communities at random and nonrandom locations in a sand-bed river. North American Journal of Fisheries Management 35: 578-585.

Araki H, Cooper B, Blouin MS. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science 318:100-103.

Araki H, Berejikian BA, Ford MJ, Blouin MS. 2008. Fitness of hatchery-reared salmonids in the wild. Evolutionary Applications 1:342-355.

Arreguín-Sánchez F. 1996. Catchability: a key parameter for fish stock assessment. Reviews in Fish Biology and Fisheries 6:221-242.

Ault TR, Cole JE, Overpeck JT, Pederson GT, Meko DM. 2014. Assessing the risk of persistent drought using climate model simulations and paleoclimatic data. Journal of Climate 27:7529-7549.

Baker JP, Hulse DW, Gregory SV, White D, Van Sickle J, Berger PA, Dole D, Schumaker NH. 2004. Alternative futures for the Willamette River Basin, Oregon. Ecological Applications 14:313-324

Bakke B. 2013. Review of hatchery and wild salmonid literature. Native Fish Society. http://wildfishconservancy.org/resources/science-library/HatcheryImpactonWildSalmonidsBakke.pdf

Beesley LS., Gwinn DC, Price A, King AJ, Gawne B, Koehn JD, Nielsen DL. 2014. Juvenile fish response to wetland inundation: how antecedent conditions can inform environmental flow policies for native fish. Journal of Applied Ecology 51: 1613-1621.

Benejam L, Alcaraz C, Benito J, Caiola N, Casals F, Maceda-Veiga A, de Sostoa A, García-Berthou E. 2012. Fish catchability and comparison of four electrofishing crews in Mediterranean streams. Fisheries Research 123:9-15.

Bennett S, Pess G, Bouwes N, Roni P, Bilby RE, Gallagher S, Ruzycki J, Buehrens T, Krueger K, Ehinger W, Anderson J, Jordan C, Bowersox B, Greene C. 2016. Progress and challenges of testing the effectiveness of stream restoration in the Pacific Northwest using intensively monitored watersheds. Fisheries 41:92-103.

Bidlack AL, Benda LE, Miewald T, Reeves GH, McMahan G. 2014. Identifying suitable habitat for Chinook salmon across a large, glaciated watershed. Transactions of the American Fisheries Society 143:689-699.

Bonar SA, Hubert WA, Willis DW (eds.). 2009. Standard methods for sampling North American Freshwater Fishes. American Fisheries Society, Bethesda, Maryland.

Breiman L. 2001. Random forests. Machine Learning 45: 5-32.

Breiman L, Friedman JH, Olshen RA, Stone CJ. 1984. Classification and regression trees. Chapman & Hall, New York.

Buchheister A, Latour RJ. 2016. Dynamic trophic linkages in a large estuarine system – support for supply-driven dietary changes using delta generalized additive mixed models. Canadian Journal of Fisheries and Aquatic Sciences 73: 5-17.

Carmichael RW, Chilcote MW, Huntington CW. 2015. Comment: natural productivity in steelhead populations of natural and hatchery origin—assessing hatchery spawner influence. Transactions of the American Fisheries Society 144:1292-1297.

Cao Y, Larsen DP, Hughes RM. 2001. Evaluating sampling sufficiency in fish assemblage surveys: a similarity-based approach. Canadian Journal of Fisheries and Aquatic Sciences 58:1782-1793.

Christie MR, Marine ML, Fox SE, French RA, Blouin MS. 2016. A single generation of domestication heritably alters the expression of hundreds of genes. Nature Communications DOI: 10.1038/ncomms10676 |www.nature.com/naturecommunications.

Colwell RK. 1997. EstimateS, version 5. Statistical estimation of species richness and shared species from samples. Available: http://viceroy.eeb.uconn.edu/estimates.

Conroy MJ Peterson JT. 2013. Decision making in natural resource management: a structured, adaptive approach. John Wiley & Sons, Hoboken, NJ.

Cowley DE. 2002. Water requirements for endangered species – Rio Grande Silvery Minnow. New Mexico Water Resources Research Institute, October 2002. Available at: http://www.wrri.nmsu.edu/publish/watcon/proc47/cowley.pdf

Cowley DE. 2006. Strategies for ecological restoration of the Middle Rio Grande in New Mexico and recovery of the Rio Grande Silvery Minnow. Reviews in Fisheries Science 14:169-186.

Creel S., Becker M, Christianson D, Droge E, Hammerschlag N, Hayward MW, Karanth U, Loveridge A, MacDonald DW, Matandiko W, M'soka J, Murray D, Rosenblatt E, Schuette P. 2015. Questionable policy for large carnivore hunting. Science 350: 1473-1475.

Dai A. 2013. Increasing drought under global warming in observations and models. Nature Climate Change 3:52-58.

Dudley RK, White GC, Platania SP, Helfrich DA. 2012. Rio Grande Silvery Minnow Population Estimation Program results from October 2011. Middle Rio Grande Endangered Species Collaborative Program. Albuquerque, New Mexico.

Dudley RK, Platania SP, White GC. 2015. Rio Grande Silver Minnow Population Monitoring Program results from February to December 2014. Middle Rio Grande Endangered Species Collaborative Program. Albuquerque, New Mexico.

Fischer JR, Paukert CP. 2009. Effects of sampling effort, assemblage similarity, and habitat heterogeneity on estimates of species richness and relative abundance of stream fishes. Canadian Journal of Fisheries and Aquatic Sciences 66:277-290.

Fleischman SJ, Catalano MJ, Clark RA, Bernard DR. 2013. An age-structured state-space stock-recruit model for Pacific salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 70:401-414.

Friedman JH, Hastie T. Tibshirani R. 2000. Additive logistic regression: a statistical view of boosting. The Annals of Statistics 28: 337-407.

Friedman JH. 2001. Greedy function approximation: a gradient boosting machine. The Annals of Statistics 29: 1189-1232.

Froeschke BF, Stunz GW, Reese Robillard MM, Williams J, Froeschke JT. 2013. A modeling and field approach to identify essential fish habitat for juvenile bay whiff (*Citharichthys spilopterus*) and southern flounder (*Paralichthys lethostigma*) with the Aransas Bay complex, TX. Estuaries and Coasts 36: 881-892.

Gammon JR. 1995. The Wabash River ecosystem II. PSI-Energy, Plainfield, IN, and Eli Lilly & Company, Indianapolis, IN.

Garfin C, Jardine A, Merideth F, Black M, LeRoy S (eds.). 2013. Assessment of climate change in the Southwest United States: a report prepared for the national climate assessment. Island Press, Washington, DC.

Hayer CA., Irwin ER. 2008. Influence of gravel mining and other factors on detection probabilities of coastal plain fishes in the Mobile River Basin, Alabama. Transactions of the American Fisheries Society 137: 1606-1620.

Haynes TB., Rosenberger AE, Lindberg MS, Whitman M, Schmutz JA. 2013. Method- and species-specific detection probabilities of fish occupancy in Arctic lakes: implications for design and management. Canadian Journal of Fisheries and Aquatic Sciences 70: 1055-1062.

Healey M. 2011. The cumulative impacts of climate change on Fraser River sockeye salmon (*Oncorhynchus nerka*) and implications for management. Canadian Journal of Fisheries and Aquatic Sciences 68: 718–737.

Hefley TJ, Tyre AJ, Blankenship EE. 2013. Fitting population growth models in the presence of measurement and detection error. Ecological Modelling 263: 244-250.

Hu, MC, Pavlicova M, Nunes EV. 2011. Zero-inflated and hurdle models of count data with extra zeros: examples from an HIV-risk reduction intervention trial. American Journal of Drug and Alcohol Abuse 37: 367-375.

Hubert WA 1996. Passive capture techniques. Pages 157-192 in Murphy BR, Willis DW (eds.). Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda.

Hubert WA, Fabrizio MC. 2007. Relative abundance and catch per unit effort. Pages 279-325 in Guy CS, Brown ML (eds.). Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Hubert WA, Pope KL, JM Dettmers. 2012. Passive capture techniques. Pages 223-265 in Zale AV, Parish DL, Sutton, TM (eds.). Fisheries techniques, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Hughes RM, Gammon JR. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Transactions of the American Fisheries Society 116:196-209.

Hughes RM, Peck DV. 2008. Acquiring data for large aquatic resource surveys: the art of compromise among science, logistics, and reality. Journal of North American Benthological Society 27:837-859.

Hughes RM, Paulsen SG, Stoddard JL. 2000. EMAP-Surface Waters: a national, multiassemblage, probability survey of ecological integrity. Hydrobiologia 422/423:429-443.

Hughes RM, Kaufmann PR, Herlihy AT, Intelmann SS, Corbett SC, Arbogast MC, Hjort RC. 2002. Electrofishing distance needed to estimate fish species richness in raftable Oregon rivers. North American Journal of Fisheries Management 22:1229-1240.

Hughes RM, Rinne JN, Calamusso B. 2005. Historical changes in large river fish assemblages of the Americas: a synthesis. American Fisheries Society Symposium 45:603-612.

Hughes RM., Herlihy AT, Gerth WJ, Pan Y. 2012. Estimating vertebrate, benthic macroinvertebrate and diatom taxa richness in raftable Pacific Northwest rivers for bioassessment purposes. Environmental Monitoring and Assessment 184:3185-3198.

Hughes RM, Dunham S, Maas-Hebner KG, Yeakley JA, Schreck CB, Harte M, Molina N, Shock CC, Kaczynski VW, Schaeffer J. 2014. A review of urban water body rehabilitation and mitigation challenges and approaches: (1) rehabilitation and remediation. Fisheries 39:18-29.

Hulse DW, Branscomb A, Payne SG. 2004. Envisioning alternatives: using citizen guidance to map future land and water use. Ecological Applications 14:325-341.

Isaak DJ, Luce CH, Rieman BE, Nagel DE, Peterson EE, Horan DL, Parkes S, Chandler GL. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20:1350–1371.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River basin fish and wildlife. Report ISAB 2007-2. Northwest Power and Conservation Council. Portland, Oregon. Available at: http://www.nwcouncil.org/fw/isab/isab2007-2.

Kanno Y, Vokoun JC, Dauwalter DC, Hughes RM, Herlihy AT, Maret TR, Patton TM. 2009. Influence of rare species on electrofishing distance–species richness relationships at stream sites. Transaction of the American Fisheries Society 138:1240-1251.

Larsen DP, Kaufmann PR, Kincaid TM, Urquhart NS. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 61:283-291.

Latour RJ. 2016. Explaining patterns of pelagic fish abundance in the Sacramento-San Joaquin delta. Estuaries and Coasts 39: 233-247

LaVigne HR, Hughes RM, Herlihy AT. 2008. Bioassessments to detect changes in Pacific Northwest river fish assemblages: a Malheur River case study. Northwest Science 82:251-258.

Lawson, PW. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. Fisheries 18(8):6-10.

Leathwick JR, Elith J, Francis MP, Hastie T, Taylor P. 2006. Variation in demersal fish species richness in the oceans surrounding New Zealand: an analysis using boosted regression trees. Marine Ecology Progress Series 321: 267-281.

Leopold LB, Wolman MG, Miller JP. 1964. Fluvial processes in geomorphology. W.H. Freeman. San Francisco, California.

Li, B., J. Cao, and J.-H. Chang. 2015. Evaluation of effectiveness of fixed-station sampling for monitoring American lobster settlement. North American Journal of Fisheries Management 35: 942-957.

Lo NC, Jacobson LD, Squire JL. 1992 Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Sciences 49: 2515-2526.

Lo NCH, Smith PE, Butler JL. 1995. Population growth of northern anchovy and Pacific sardine using stage-specific matrix models. Marine Ecology Progress Series 127:15-26.

MacKenzie D I, Nichols JD, Royle JA, Pollock KH, Bailey LL, Hines JE. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier, Burlington, Vermont.

Martin TG, Wintle BA, Rhodes JR, Kuhnert PM, Field SA, Low-Choy SJ, Tyre AJ, Possingham HP. 2005. Zero tolerance ecology: improving ecological inference by modeling the source of zero observations. Ecology Letters 8: 1235 – 1246.

Meador MR, Cuffney TF, Gurtz ME. 1993. Methods for sampling fish communities as part of the national water-quality assessment program. USGS Open File Report 93-104 U.S. Geological Survey; Raleigh, NC.

Melillo JM, Richmond TC, Yohe GW (eds.) Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program. Doi:10.7930/J04Q7RWX.

Miller K, Huettmann F, Norcross B, Lorenz M. 2014. Multivariate random forest models of estuarine-associated fish and invertebrate communities. Marine Ecology Progress Series 500: 159-174.

Mulvey M, Leferink R, Borisenko A. 2009. Willamette Basin rivers and streams assessment. Oregon Department of Environmental Quality, Hillsboro, OR.

Myers RA, Pepin P. 1990. The robustness of lognormal-based estimators of abundance. Biometrics 46: 1185-1192.

NEON (National Ecological Observatory Network). 2014. Fish sampling in wadeable and non-wadeable streams and lakes. https://www.google.com/search?client=safari&rls=en&q=NEON.DOC.001295AOS+Protocol+and+Procedure:+Fish+Sampling+in+Wadeable+Streams&ie=UTF-8&oe=UTF-8#q=FISH+SAMPLING+IN+WADEABLE+AND+NON+WADEABLE+STREAMS+AND+LAKES+(RFI-0276-AQU) (Accessed January 2016).

Nie MA, Schultz CA. 2012. Decision-making triggers in adaptive management. Conservation Biology 26:1137–1144.

Norcross BL., Muter F-J, Holladay BA. 1997. Habitat models for juvenile pleuronectids around Kodiak Island, Alaska. Fishery Bulletin 95: 504-520.

Norfolk. 2014. Norfolk Resiliency Strategy. Report from Mayor P. D.Fraim. (Available at: http://nfkresilientcity.org/wp-content/uploads/2015/10/Norfolk_Resilient_Strategy_October_2015.pdf)

Novak R, Kennen JG, Abele RW, Baschon CF, Carlisle DM, Dlugolecki L, Flotermersch JE, Ford P, Fowler J, Galer R, Gordon LP, Hansen SN, Herbold B, Johnson TE, Johnston JM, Konrad CP, Leamond B, Seelbach PW. 2015. Protecting aquatic life from effects of hydrologic alteration. U.S. Geological Survey Scientific Investigations Report 2015–5160, U.S. Environmental Protection Agency Report 822-P-15-002. (Available at: http://www2.epa.gov/wqc/aquatic life-ambient-water quality-criteria)

NYC. 2013. A Stronger, More Resilient New York. Report from Mayor M. R. Bloomberg's office. (Available at http://s-media.nyc.gov/agencies/sirr/SIRR_singles_Lo_res.pdf)

Olden J, Jackson DA. 2002. A comparison of statistical approaches for modelling fish species distributions. Freshwater Biology 47: 1976-1995.

Olsen AR, Peck DV. 2008. Survey design and extent estimates for the Wadeable Streams Assessment. Journal of the North American Benthological Society 27:822-836.

Ortiz M, Legault CM, Ehrhart NM. 2000. An alternative method for estimating bycatch from the US shrimp trawl fishery in the Gulf of Mexico, 1972-1995. Fishery Bulletin 98: 583-599.

Osborne MJ, Benavides MA, Alo D, Turner TF. 2006. Genetic effects of hatchery propagation and rearing in the endangered Rio Grande Silvery Minnow, *Hybognathus amarus*. Reviews in Fisheries Science. 14:127-138.

Osborne MJ, Carson EW, Turner TF. 2012. Genetic monitoring and complex population dynamics: insights from a 12-year study of the Rio Grande Silvery Minnow. Evolutionary Applications 5:553-574.

Osborne MJ, Perez TL, Altenbach CS, Turner TF. 2013. Genetic analyses of captive spawning strategies for the endangered Rio Grande Silvery Minnow. Journal of Heredity 104:437-446.

Paulsen CM, Hinrichsen RA, FisherTR. 2007. Measure twice, estimate once: Pacific salmon population viability analysis for highly variable populations. Transactions of the American Fisheries Society 136:346-364.

Paulsen SG, Mayio A, Peck DV, Stoddard JL, Tarquinio E. Holdsworth SM, Van Sickle J, Yuan LL, Hawkins CP, Herlihy AT, Kaufmann PR, Barbour MT, Larsen DP, Olsen AR. 2008. Condition of stream ecosystems in the U.S.: an overview of the first national assessment. Journal of the North American Benthological Society 27:812-821.

Peoples BK, Frimpong EA. 2011. Among-pass, interregional, and single- versus multiple-season comparisons of detection probabilities of stream fishes. Transactions of the American Fisheries Society 140: 67-83.

Pont D, Hugueny B, Beier U, Goffaux D, Melcher A, Noble R, Rogers C, Roset N, Schmutz S. 2006. Assessing river biotic condition at a continental scale: a European approach using functional metrics and fish assemblages. Journal of Applied Ecology 43:70-80.

Quiñones RM, Holyoak M, Johnson ML, Moyle PB. 2014. Potential factors affecting survival differ by run-timing and location: linear mixed-effects models of Pacific salmonids (*Oncorhynchus* spp.) in the Klamath River, California. PLoS ONE DOI: 10.1371/journal.pone.0098392.

Quist MC, Gerow KG, Bower MR, Hubert WA. 2006. Random versus fixed-site sampling when monitoring relative abundance of fishes in headwater streams of the upper Colorado River basin. North American Journal of Fisheries Management 26: 1011-1019.

Rathert D, White D, Sifneos JC, Hughes RM. 1999. Environmental correlates of species richness for native freshwater fish in Oregon, USA. Journal of Biogeography 26: 257-273.

Rist L, Campbell BM, Frost P. 2012. Adaptive management: where are we now? Environmental Conservation 40:5–8.

Roni P. 2005. Monitoring stream and watershed restoration. American Fisheries Society, Bethesda, Maryland.

Rose KA, Kimmerer WJ, Edwards KP, Bennett WA. 2013a. Individual-based modeling of delta smelt population dynamics in the Upper San Francisco estuary: I. Model description and baseline results. Transactions of the American Fisheries Society 142: 1238-1259.

Rose KA, Kimmerer WJ, Edwards KP, Bennett WA.. 2013b. Individual-based modeling of delta smelt population dynamics in the Upper San Francisco estuary: II. Alternative baselines and good versus bad years. Transactions of the American Fisheries Society 142: 1260-1272.

Rowland EL, Cross MS, Hartmann H. 2014. Considering multiple futures: scenario planning to address uncertainty in natural resource conservation. U.S. Fish and Wildlife Service and Wildlife Conservation Society. (Available at: http://www.fws.gov/home/feature/2014/pdf/Final Scenario Planning Document.pdf).

Runge MC. 2011. An introduction to adaptive management for threatened and endangered species. Journal of Fish and Wildlife Management 2:220–233.

Schaaf WE, Peters DS, Vaughan DS, Coston-Clements L, Krouse CW. 1987. Fish population responses to chronic and acute pollution: the influence of life history strategies. Estuaries 10:267-275.

Schmutz S, Cowx IG, Haidvogl G, Pont D. 2007. Fish-based methods for assessing European running waters: a synthesis. Fisheries Management and Ecology 14:369-380.

Simmons M, Tucker A, Chadderton WL, Jerde CL, Mahon AR. 2016. Active and passive environmental DNA surveillance of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences73:76-83.

Singh AA, Sakuramoto K, Suzuki N. 2014. Model for stock-recruitment dynamics of the Peruvian anchoveta (*Eugraulis ringens*) off Peru. Journal of Agricultural Science 5:140-151.

Smith KL, Jones ML. 2005. Watershed-level sampling effort requirements for determining riverine fish species composition. Canadian Journal of Fisheries and Aquatic Sciences 62:1580-1588.

Stephens DB. 2015. Survey of the Executive Committee on fish population monitoring needs summary report: Middle Rio Grande Endangered Species Collaborative Program. Daniel B. Stephens & Associates, Albuquerque, NM.

Stevens Jr. DL, Olsen AR. 2004. Spatially-balanced sampling of natural resources. Journal of the American Statistical Association 99(465):262-278.

Takahara T, Minamoto T, Yamanaka H, Doi H, Kawabata Z. 2012. Estimation of fish biomass using environmental DNA. PLoS ONE 7(4): e35868. doi:10.1371/journal.pone.0035868.

Tang M, Jiao Y, Fabrizio MC, Greenlee RS, Orth DJ. *In review*. Hierarchical Bayesian approach to standardize catch rates of blue catfish in tidal rivers of Virginia from multiple surveys using multiple gears. Fisheries Research.

Then AY, Hoenig JM, Hall NG, Hewitt D. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science 72: 82-92.

Thompson DM. 2006. Did the pre-1980 use of instream structures improve streams? A reanalysis of historical data. Ecological Applications 16:784–796.

Thorson, JT, IJ Stewart, and AE Punt. 2012. Development and application of an agent-based model to evaluate methods for estimating relative abundance indices for shoaling fish such as Pacific rockfish (*Sebastes* spp.). ICES Journal of Marine Science 69: 635–647.

Tockner K, Malard F, Ward JV. 2000. An extension of the flood pulse concept. Hydrological Processes 14:2861-2883.

Trushenski JT, Blankenship HL, Bowker JD, Flagg TA, Hesse JA, Leber KM, MacKinlay DD, Maynard DJ, Moffitt CM, Mudrak VA, Scribner KT, Stuewe SF, Sweka JA, Whelan GE, Young-Dubovsky C. 2015. Introduction to a special section: hatcheries and management of aquatic resources (HaMAR)—considerations for use of hatcheries and hatchery-origin fish. North American Journal of Aquaculture 77:327-342.

Tuckey TD, Fabrizio MC. 2013. Influence of survey design on fish assemblages: implications from a study in Chesapeake Bay tributaries. Transactions of the American Fisheries Society 142:957-973.

USEPA (U.S. Environmental Protection Agency). 2009. National Lakes Assessment: a collaborative survey of the Nation's lakes. EPA 841/R-09/001. Office of Water/Office of Research and Development, Washington, DC.

_____. 2013. National Rivers and Streams Assessment 2008-2009: a collaborative survey. EPA/841/D-13/001. Office of Wetlands, Oceans and Watersheds/Office of Research and Development, Washington, DC.

_____. 2015. National Wetland Condition Assessment 2011: a collaborative survey of the Nation's wetlands. EPA-843-R-15-005. Office of Wetlands, Oceans and Watersheds/Office of Research and Development, Washington, DC.

USFWS (U.S. Fish & Wildlife Service). 2010. Rio Grande Silvery Minnow (Hybognathus amarus) recovery plan, first revision. Albuquerque, NM.

Van der Meer J. 1997. Sampling design of monitoring programmes for marine benthos: a comparison between the use of fixed versus randomly selected stations. Journal of Sea Research 37: 167-179.

Walters C. 1986. Adaptive management of renewable resources. The Blackburn Press. Caldwell, New Jersey.

Wang L, Lyons J, Rasmussen P, Seelbach P, Simon T, Wiley M, Kanehl P, Baker E, Niemela S, Stewart PM. 2003. Watershed, reach, and riparian influences on stream fish assemblages in the Northern Lakes and Forest Ecoregion, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 60:491-503.

Weber MJ, Brown ML.2013. Density-dependence and environmental conditions regulate recruitment and first-year growth of common carp in shallow lakes. Transactions of the American Fisheries Society 142:471-482.

Widmer AM, Burckhardt LL, Kehmeier JW, Gonzales EJ, Medley CN, Valdez RA. 2010. Detection and population estimation for small-bodied fishes in a sand-bed river. North American Journal of Fisheries Management 30:1553-1570.

Wilberg MJ, Thorson JT, Linton BC, Berkson J. 2010. Incorporating time-varying catchability into population dynamic stock assessment models. Reviews in Fisheries Science 18:7-24.

Williams BD, Fabrizio MC. 2011. Detectability of estuarine fishes in a beach seine survey of tidal tributaries of lower Chesapeake Bay. Transactions of the American Fisheries Society 140: 1340-1350.

Williams RN, Bisson PA, Bottom DL, Calvin LD, Coutant CC, Erho Jr. MW, Frissell CA, Lichatowich JA, Liss WJ, McConnaha WE, Mundy PR, Stanford JA, Whitney RR. 1999. Return to the river: scientific issues in the restoration of salmonid fishes in the Columbia River. Fisheries 24(3):10-19.

Zimmerman MS, Kinsel C, Beamer E, Connor EJ, Pflug DE. 2015. Abundance, survival, and life history strategies of juvenile Chinook salmon in the Skagit River, Washington. Transactions of the American Fisheries Society 144:627-641.

Zuur AF, Ieno EN. Walker HJ, Saveliev AA, Smith GM. 2009. Mixed effects models and extensions in Ecology with R. Springer Science+Business Media, New York.

Appendix A
Agenda

Fish Population Monitoring Workshop

DRAFT AGENDA: 9/13/2015

Date: December 8–10, 2015

Location: Isleta Resort and Casino, 11000 Broadway SE, Albuquerque, NM 87105

Purpose: The purpose of this workshop is to convene external scientists, program scientists, and interested parties **to evaluate the current fish population monitoring program for the Middle Rio Grande, New Mexico**, **and to recommend updates, as necessary,** in order to reliably measure the effects of water management actions and conservation measures on the Rio Grande silvery minnow. Note that this workshop is not intended to determine sufficient progress metrics or recovery plan criteria. A report will be provided by external scientists 90 days after the workshop.

Agenda:

Day 1: December 8, 2015 *AM* 8:00 – 8:05 am: Welcome from Collaborative Program Representatives (Brent Rhees or Rick Billings to give a welcome)

8:05 – 8:40 am: Introduction and Description of Workshop (Wayne Hubert, Facilitator)

a. Purpose and goal of workshop
b. Logistics and ground rules (lunch, dinner, restrooms, cell phones, etc.)
c. Introduction of External Experts
d. Introduction of Program Scientists
e. Questions from Program and External scientists

8:40 – 9:50 am: Overview of Sampling Design (Robert Dudley, American Southwest Ichthyological Researchers). Focus on sampling methodology and data analysis.

9:50 – 10:00 am: Break

AM—Question #1: Is the CPUE index appropriate for monitoring the RGSM in the Middle Rio Grande?

10:00 -- 12:00 am: Discuss Issues to Question #1

Lunch 12:00 – 1:30 pm

PM—Question #2: Are the monitoring plan and sampling design appropriate for tracking the status and trend of the RGSM in the Middle Rio Grande?

1:30 – 3:00 pm: Discuss Issues to Question #2

3:00 – 3:10 pm: Break

3:10 – 5:00 pm: Discuss Issues and Wrap-up of Question #2

Day 2: December 9, 2015

AM—Question #3: Are the statistical analysis used in the monitoring program appropriate and in line with data distribution and characteristics? Are there additional analytical techniques that could be utilized that would improve the use of CPUE?

8:00 – 10:30 am: Discuss Issues to Question #3

10:30 – 10:40 am: Break

10:40 – 12:00 noon: Discuss Issues and Wrap-up of Question #3

Lunch 12:00 – 1:30 pm

PM—Question #4: What revisions can be made to the sampling design to improve accuracy, precision, and power to detect change in RGSM abundance?

1:30 – 3:00 pm: Discuss Issues to Question #4

3:00 – 3:10 pm: Break

3:10 – 5:00 pm: Discuss Issues and Wrap-up of Question #4

7:00 – 9:00 pm: Meeting of External Scientists Only

Day 3: December 10, 2015

AM—Summary of Initial Responses by External Experts (preliminary thoughts)

8:00-10:00am: Meeting of External Scientists Only

10:00 – 10:30 am: Question #1

10:30 – 11:00 am: Question #2

11:00 – 11:30 am: Question #3

11:30 – 12:00 pm: Question #4

Lunch 12:00 – 1:30 pm

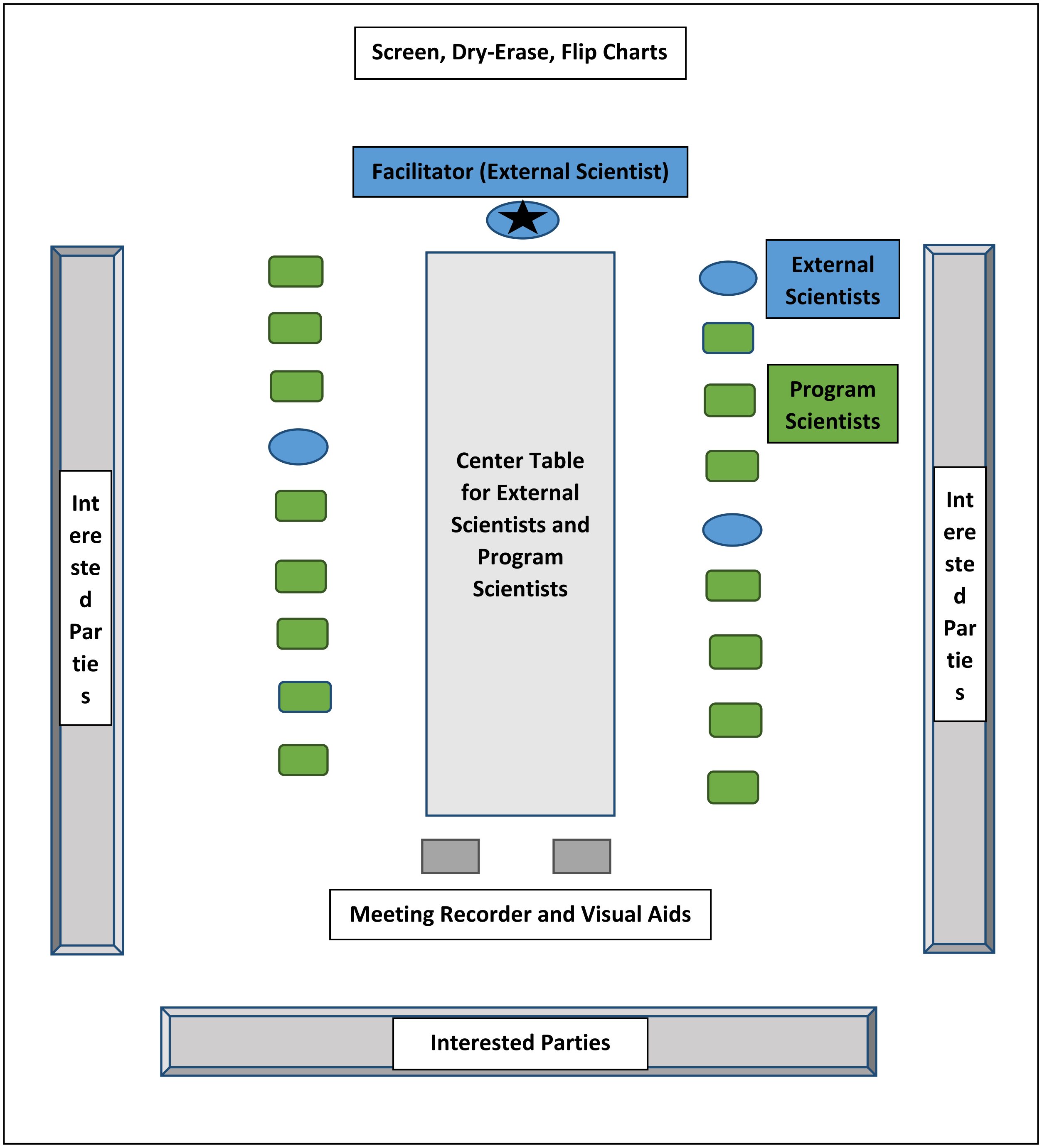
PM—Open Discussion

1:30 – 3:30 pm: Open Discussion—Comments and questions accepted from Program Scientists and Interested Parties

3:30 – 3:40 pm: Break

3:40 – 5:00 pm: Wrap-up

Workshop Setup



Appendix B
Ground Rules

Fish Population Monitoring Workshop Ground Rules

Summary of the process:

The focus of Day 1 and Day 2 is to assimilate as much pertinent scientific information as possible regarding fish population monitoring on the Middle Rio Grande. The assimilation of scientific information will be used by the External Experts. At the end of Day 2, the External Experts will meet and summarize their initial responses/preliminary thoughts regarding the fish monitoring program. During the morning of Day 3, the External Experts will present their initial responses/preliminary thoughts to the Program Scientists and Interested Parties in attendance. The afternoon of Day 3 is for an Open Discussion to allow Program Scientists and Interested Parties to comment on the scientific information assimilated during the workshop and the initial responses/preliminary thoughts of the Expert Scientists. Following the workshop, the External Experts will develop their report on fish population monitoring and submit it.

The guiding principles for the workshop:

(1) Respect the dignity of all participants,

(2) Address the scientific aspects of monitoring, and

(3) Facilitate the assimilation of scientific information for use by external scientists in providing their assessment the fish monitoring program in the Middle Rio Grande.

Facilitator:

Assists the workshop participants to understand their common objectives and help them to achieve these objectives.

Chair person – recognize speakers, timekeeper, follow agenda.

Not a lecturer – will provide introductions to sessions addressing specific questions and introduce scheduled speakers.

Interpreter – guide speakers to achieve understanding of their points and assure accurate recording.

Active, unbiased External Expert.

Ground rules:

No opinions regarding the abilities, backgrounds, or policies of any individuals, groups, or agencies are to be expressed by Program Scientists or External Experts during the workshop.

All Program Scientists and External Experts are asked to address only the **scientific aspects** of the questions. Opinions or debates regarding policy issues are not to be expressed and will not be recorded.

When recognized by the facilitator, the speakers will identify themselves by name and address the facilitator, not another Program Scientist or External Expert.

Speakers will limit comments to less than 5 minutes.

The pertinent point(s) made of each speaker will typed, projected, and saved for future reference by External Experts and workshop documentation.

External Experts will be given preference to ask questions and provide comments.

When a Program Scientist has been recognized to speak and their point(s) is recorded, that person will not be recognized to speak again until all other Program Scientists have had an opportunity to speak to the question.

When a point has been made and recorded, it is not to be made again by another speaker. The focus will be on recording all pertinent information regarding a question, not to determine the strength of support by Program Scientists for a particular point. However, further clarification of a point is appropriate.

Only Program Scientists and External Experts will be recognized to speak during the workshop with the exception of the Open Discussion on the afternoon of Day 3. At that time Interested Parties will be recognized. Interested Parties who are recognized to speak will provide their name, the organization they represent, and then state their comment. Pertinent comments will be recorded and identified as those of the speaker and organization they represent.

During and following the workshop, Program Scientists and Interested Parties are not to communicate with the Expert Scientists outside of the formal workshop proceedings regarding the fish monitoring program. The intention is that the Expert Scientists provide their assessment of the fish monitoring program based on the scientific information made available to them through the workshop without bias.

The sound of all communication devices will be turned off during the workshop sessions. If a participant must communicate via a device during a workshop session, either by voice or text, they are asked to exit the meeting room to conduct their business.

There will be no audio or visual recording of the workshop sessions by participants or interested parties.

Beyond the ground rules:

The workshop is to be enjoyable for the workshop participants and the workshop facilitator. Let's make it a joyful learning environment and recognize that we all have shared values. Get to know each other on a personal basis while participating in the workshop.

There will be no consistent seating arrangement. Each session will begin with place names in a different location. Program Scientists or External Experts should let the facilitator know if they have hearing or sight limitations. Also, each session will begin with a brief icebreaking exercise.

Appendix C
Questions

Attachment 1. Questions for Experts—Population Monitoring Workshop

Preamble

The Population Monitoring Workgroup (Workgroup) has developed the following set of questions for the external experts to address at the Population Monitoring Workshop and in their report to the Workgroup. The questions are intended to focus the experts on the issues of importance as reflected by the Workgroup and members of the Executive Committee of the Middle Rio Grande Endangered Species Collaborative Program. The external experts are asked to specifically address each question (Q1–Q4) in their report. Additional sub-questions (1, 2, 3…) are included to further inform each question, but the experts are not asked to specifically address these sub-questions. A complete set of detailed questions developed by the Workgroup is included in Attachment #1 to reflect the deliberation of the Workgroup and as additional information for the experts.

Question and Sub-Questions for Experts:

Q1. Are the monitoring plan and sampling design appropriate for tracking the status and trend of the RGSM in the Middle Rio Grande?

1. How many sample sites should be selected?

2. Should sample sites be spatially stratified (e.g., by reach, mesohabitat, etc.)?

3. Should sample site selection be fixed or random?

4. How often should samples be taken: monthly, bimonthly, quarterly?

5. What is the best time of year to monitor RGSM abundance (relative to spawning, temperature, flow, survival rate, etc.)?

6. RGSM are distributed in highly clumped fashion; how should sampling be done in and around structure where fish aggregate, such as debris piles?

7. Should monitoring be able to detect very low densities of RGSM, or should there be supplemental sampling when the population is at low abundance?

8. Is seining the most appropriate gear type, or should other gears be used instead of, or in addition to, seining (e.g., fyke nets, electrofishing, etc.)?

9. Over 25% of the CPUEs are zeros, where no RGSM were caught in a pool of seine hauls. The large number of zeros preclude parametric analysis (even when data are log-transformed). Should sampling design be refined to reduce zero catches?

Q2. Is the CPUE index appropriate for monitoring the RGSM in the Middle Rio Grande?

1. Is CPUE the best index for monitoring the status and trend of RGSM and associated fish species?

2. Should population estimation (e.g., depletion, mark-recapture, etc.) be used instead of CPUE or to verify accuracy?

3. Can a different index—or a modification of CPUE—be used with the data since 1993 and not compromise the continuity of the 20+ year database?

4. Given the variability in river flow over the year and during sampling, does flow affect CPUE and introduce variability or error when CPUE is compared over time or space; is it possible to adjust for flow differences at sampling?

5. Can CPUE data be used to derive estimates of demographic parameters, such as survival, recruitment, cohort strength, hatching dates, etc?

6. Is the monitoring program suitable for measuring recovery standards and for sufficient progress metrics?

7. Can CPUE data be used to evaluate population viability and self-sustainability?

Q3. What revisions can be made to the sampling design to improve accuracy, precision, and power to detect change in RGSM abundance?

1. Can the sampling design be revised to improve precision and change detection and yet maintain consistency of data over time since 1993?

2. What level of precision and change detection should be targeted for monitoring RGSM?

3. How does cost balance with accuracy, precision, and power to detect change?

4. How does fish stress and injury balance with accuracy, precision, and power to detect change?

Q4. Are the statistical analysis used in the monitoring program appropriate and in line with data distribution and characteristics? Are there additional analytical techniques that could be utilized that would improve the use of CPUE?

1. Samples are collected with individual seine hauls that are not distinguished in the database before 2006, and mean CPUEs are computed from the “pool” of seine hauls taken at a given sampling site (~20 per site). Should data of each seine haul be used to compute mean CPUE rather than the pool of fish divided by the pool of square meters seined?

2. The zero-inflated data preclude computation of parametric mean and variance and a mixture model combining the binomial distribution with the lognormal distribution was introduced in 2013 to compute mean CPUE and variance. Is this the best solution for estimating mean CPUE and variance, or would another model be better suited (e.g., Poisson) and is use of a predictor model practical for managers to understand?

3. What is the role of occupancy models in monitoring the RGSM?

4. Is the monitoring program sufficiently robust and sensitive for detecting change in RGSM abundance when a management action is implemented?

5. What management questions can--and cannot—be addressed with the current monitoring program or a revision of the program?

Attachment #1: Detailed Questions Developed by the Workgroup

A. Questions Compiled by Population Monitoring Workgroup (9/9/2014):

1. How do seine haul catches (CPUE) compare with other species?
    a. How does it characterize and compare to how well seining tracks other species?
2. Is the current sampling design missing fish?
    a. Does the distribution of sampling mimic the distribution of fish? Is that a bias?
3. How do different gear types affect capture probability and CPUE?
    a. Supplemental ways to monitor minnow/small bodied fish.
4. Is some of the variability controllable?
    a. Sources: sampling variability and resource variability
5. Has the CPUE vs population estimate been resolved?
    a. Frequency of population estimate, population estimate is low abundance
6. Are CPUE data "zero-inflated"?
    a. Does it matter?
7. How precise do we need to be with CPUE for management actions?
    a. What types of management actions are measureable?
8. How effective are mark/recap for silvery minnow?
    a. Thomas A has provided input on this during his presentation at the working meeting
9. What are key variables that affect CPUE (e.g. flow)?
    a. Can anything be done? Is that an uncontrollable source of variability?
    b. What are the key variables that affect the species
    c. source variability = species abundance
10. Would stratified sampling by mesohabitat improve precision (as covariate)?
    a. They already have certain types of mesohabitats that they have to sample, already stratified by mesohabitat at each sampling location
    b. How would sampling a certain type of mesohabitat rather than sampling mesohabitats at a fixed location affect the data?

   c. Analysis of current sampling by mesohabitat data has not been done; should this be done?

11. Does randomization of sites improve precision?
    a. Site or reach has effect on detection probability
12. Is stratification by reach necessary?
13. Review use of mix model
14. How do physical changes with flow affect CPUE? By location
    a. Does that make a difference over time?
15. Is there value from collections in addition to monitoring? e.g. S= e-zt (catch curves), cohort strength
16. Timing of CPUE?
    a. Should it be prior to spawning?
    b. Handle fish prior to spawning?
17. Is current monitoring program sufficiently sensitive to detect small changes? (Q20)
18. Changes at small population size.
19. How much will increased sample size improve precision? Cost?
20. Would “effects monitoring” as a supplemental aspect help to determine effect of management action?
21. When CPUE is low or “zero” at all sites - what action should be taken?
    a. e.g., supplemental monitoring; consecutive months?
22. How do costs balance against precision?
23. What are advantages of October CPUE vs other times?
    a. CPUE variability and flow variability
24. How does the dispersion parameter change with population size?
    a. How does K vary with the mean? How does the clumping change with population? K in negative binomial.

B. <u>Questions from Jason Davis</u>:

Q1. Do the techniques, methods, and data used and the results provided support the conclusions and interpretations that are provided in the annual reports issued and peer reviewed articles authored by the PIs for the Monitoring Projects?

Q2. Do the techniques, methods, and data used and the results provided support the conclusions and interpretations that are provided in the Fish Monitoring Plan and updates to that Plan, authored by the MRG ESA CP (dated September 22, 2006?

Q3. Are the RGSM CPUE data appropriate in relation to the life history of RGSM (as is supported by relevant, peer-reviewed reports or other references in the Genetics Project work products)?

Q4. Was the experimental design and sampling methodology appropriate and did the methods have sufficient power to detect the trends and findings that were reported?

Q5. Does the study design, and methods of monitoring and assessment achieve the goals and objectives of the Monitoring Plan?

Q6. What statistical analyses were used and were the assumptions of those analyses met?

Q7. What other scientifically-robust interpretations could be made using the same data and results of the Monitoring Projects?

Q8. When there are gaps or uncertainties in the information or data are they clearly identified in the reports and publications issued? Does the Panel unanimously recommend remedies to address any gaps or uncertainties?

Q9. Are there additional analytical techniques that could be utilized that would improve the use of CPUE?

Q10. What parameters should be measured and reported that will most efficiently track spatial and temporal trends in RGSM distribution and abundance?

Q12. How often (at what frequency) should the monitoring be implemented (based on the life history of RGSM and current water management practices?

Q13. What changes would the Panelists recommend to improve the use of CPUE? Please support recommendations with relevant citations, reasoning, and estimates of the relative power to detect changes in a population? How can past data be used with any potential changes to the monitoring program?

C. Questions from Rich Valdez:

1. Is there an ideal number of samples collected by month?
2. How many months should be sampled each year? How many samples should be taken?
3. Do the different number of samples and months sampled affect comparability of CPUE?
4. Should sampling sites be fixed locations?
5. Should numbers of samples by site be evenly distributed (note that in recent years, number of samples by site is approximately equal)?
6. Number of samples over time and by reach have varied; are densities (CPUE) comparable over time?
7. Should numbers of samples by site be evenly distributed?
8. Should three reaches be treated as strata for purpose of distributing samples?
9. Is relatively higher density reflected across all stations and reaches?
10. Is relatively low density reflected across all stations and reaches?
11. What is causing the high number of zero catches—and is that necessarily bad?
12. Should monitoring be done at a time when data variability is lowest?
13. The numbers of samples over the last 20 years (1993-2013) have varied, especially before 2002. Are the data over the entire time period comparable for determining the status and trend of the RGSM?
14. Fixed locations (i.e., 20 sampling sites) have been used to collect monitoring data. Should sampling locations be fixed or should samples be taken at different locations, such as with a stratified random design?
15. Samples are collected from fixed sampling sites within each of three reaches. Should the reaches be treated as different strata for the purpose of sample allocation?
16. Mean CPUE is based on October or “putative” October samples (i.e., samples taken in adjacent months and included with October samples). Is October the best time of year to sample or would sampling at another time reduce data variability?
17. Samples are collected with individual seine hauls that are distinguished in the database starting in 2006, and mean CPUEs are computed from the “pool” of samples taken at a given sampling site. Should data of each seine haul be used to compute mean CPUE rather than the pool of fish divided by the pool of square meters seined?

18. Over 25% of the CPUEs are zeros, where no RGSM were caught in a given seine haul. Should sampling design be refined to reduce the number of zero catches?

19. The large number of zeros in the CPUE data preclude parametric analysis (even when the data are log-transformed). Is resolving the distribution of the data with a model or mixture model the most appropriate approach?

20. The zero-inflated data preclude computation of mean and variance and a mixture model combining the binomial distribution with the lognormal distribution was introduced in 2013 (see Figure S-1). Is this the best solution for estimating mean CPUE and variance, or would another model be better suited (e.g., Poisson)—and is this approach using a predictor model practical for managers to understand?

Appendix D
List of Provided Reference Materials

List of materials provided to Expert Panelists by the Collaborative Program so that they could prepare for the Workshop.

File Name	Document Name	Listed Authors
1_Basic Sampling Design and Methods 9-10-2014.pdf	Basic Sampling Design and Methods; Rio Grande Silvery Minnow Population Monitoring Program; Working Meeting of the Population Monitoring Workshop Planning Committee; September 9, 2014	None Listed
1_RGSM_PopulationMonitoring_2011_Draft.pdf	Rio Grande Silvery Minnow Population Monitoring Program Results From December 2010 to October 2011-Draft	Dudley RK and Platania SP, 2012
1_Widmer et al. 2010 (Detection).pdf	Detection and Population Estimation for Small-Bodied Fishes in a Sand Bed River	Widmer AM et al. 2011
2_Archdeacon and Davenport 2013 (Pecos comment).pdf	Comment: Detection and Population Estimation for Small-Bodied Fishes in a Sand Bed River	Archdeacon TP and Davenport SR 2013
2_Overview of Pop Mon Program and Database 9-10-2014.pdf	Overview of Population Monitoring Program and Database	None Listed. 2014
2_RGSM_PopulationMonitoring_2014_draft.pdf	Rio Grande Silvery Minnow Population Monitoring Program Results From February to December 2014	Dudley RK, Platania SP, and White GC. 2015
3_Archdeacon_2014_Catch per unit effort.pdf	Catch per unit effort in the Rio Grande, simplified	Archdeacon TP 2014
3_RGSM_PopulationEstimate_2011_Final.pdf	Rio Grande Silvery Minnow Population Estimation Program Results from October 2011	Dudley RG, White GC, Platania SP, and Helfrich DA. 2012
3_Widmer et al. 2013 (Response).pdf	Detection and Population Estimation for Small-Bodied Fishes in a Sand Bed River: Response to Comment	Widmer AM et al. 2013
4_jai12447.pdf	An evaluation of multiple-pass seining to monitor blackstripe topminnow Fundulus notatus (Rafinesque, 1820) in the Sydenham River (Ontario, Canada)	Reid SM and Hogg S. 2013
4_Response to preliminary question (R code example).pdf	Response to preliminary questions for invited scientists	U.S. Fish and Wildlife Service
5_Bayley-Herendeen_2000_.pdf	The efficiency of a seine net	Bayley PB and Heredeen RA. 2011
6_UJFM-2014-0228_Community Comparison.pdf	Comparison of Fish Communities at Random and Nonrandom Locations in a Sand-Bed River	Archdeacon TP, Henderson KR, Austring TG, and Cook RL. 2015
DEPARTMENT OF THE INTERIOR Mail - Removal of three expert scientists from consideration.pdf	Removal of three expert scientists from consideration	Davis JE 2015
Provisional_RGSM_Pop_Mon_Database_1993-2014.xls	Provisional_RGSM_Pop_Mon_Database_1993-2014	None Listed
Summary Report_2-19-2015.pdf	Summary of the Executive Committee on Fish Population Monitoring Needs Summary Report	Daniel B. Stephens & Associates, Inc. 2015

Appendix E
Attendees

MEETING SIGN-IN SHEET

Project: Rio Grande Silvery Minnow Population Monitoring Workshop	**Meeting Date:** Tuesday, December 8, 2015
Facilitator: Wayne Hubert	Place/Room: Isleta Resort, Seminar Meeting Room

	Name	Organization	Phone	E-Mail
1	Matt Cusack	Atkins	919-431-5255	Matt.cusack@atkinsglobal.com
2	Mark McKinstry	BoR	8015731161	mmckinstry@usbr.gov
	Wayne Hubert	Facilitator	307-760-8723	whubert@uwyo.edu
3	Robert Dudley	ASIR/UNM	505-247-9337	Robert_Dudley@asirllc.com
4	Thomas Archdeacon	USFWS	505 342 9900	thomas_archdeacon@fws.gov
5	Bill Pine	Univ FL / MRGCD	352 225 1643	floridarivers@gmail.com
6	Gary C White	Colo State/ASIR	9704826889	Gary.White@ColoState.edu
7	Rich Valdez	SWCA/NMISC	(435) 752-9606	valdezra@aol.com
8	Michael Porter	USACE	(505) 342-3264	michael.d.porter@usace.army.mil
9	Mike Marcus	APA	505 379-6891	mdmenv@gmail.com
10	BOB HUGHES	AOI	208 354 2632	HUGHES.BOB@AMNISOPES.COM
11	TOM SINCLAIR	USFWS	505-321-9130	thomas_sinclair@fws.gov
12	Steven Platania	ASIR	505 247 9337	platania@unm.edu
13	David Gensler	MRGCD	505 247 0234	dgensler@mrgcd.com
14	David R. Stewart	USFWS	3072314778	david_stewart@fws.gov
15	Jen Bachus	BoR	505-462-3596	jbachus@usbr.gov
16	Brian Hobbs	BOR	505 462 3564	bhobbs@usbr.gov
17	Juddson Sechrist	BOR	505-462-3601	jsechrist@usbr.gov
18	Nathan Schroeder	PSA	505-771-6919	Nathan.Schroeder@santaana-nsn.gov

	Name	Organization	Phone	E-Mail
19	Jason E. Davis	USFWS	505-342-9900	Jason_E_Davis@fws.gov
20	Joel D. Lusk	USFWS	505-761-4709	joel_lusk@fws.gov
21	Julie Alcon	US Corps of Engineers	505-342-3281	julie.a.alcon@usace.army.m
22	Dana Price	US Army Corps of Engineers	505.342.3378	dana.m.price@usace.army.mil
23	Justin Reale	US Army Corps of Engineers	505 342-3138	justin.k.reale@usace.army.mil
24	David Campbell	USFWS	505-761-4745	david_campbell@fws.gov
25	Ryan Vazquez	Texas Tech	806-834-4987	ryan.r.vazquez@ttu.edu
26	Grace Haggerty	nmisc	505 383-4042	grace.haggerty@state.nm.us
27	Malia Volke	New Mexico Dept. of Game and Fish	505-476-8160	malia.volke@state.nm.us
28	Mary Fabrizio	VIMS	804.684.7308	mfabrizio@vims.edu
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

	Name	Organization	Phone	E-Mail
41	Wally Murphy	USFWS	761-4781	wally_murphy@FWS.GOV
42	Rolf Schmidt-Petersen	NMISC	827-6160	rolf.schmidt@state.nm.us
43	Janet Jarratt	APA	620-1136	jj@jjwater.info
44	Chuck Hayes	NMDGF	476-8114	chuck.hayes@state.nm.us
45	Eric Gonzales	SWCA / NMISC	5172858132	eGonzales@swca.com
46	Jim Brooks	Self	505 331 5926	arroyodejaime@gmail.com
47	Todd Caplan	GeoSystems Analysis	505 980-0336	todd@gsanalysis.com
48	Gene Wilde	Texas Tech Univ	806 8340265	gene.wilde@ttu.edu
49	Aaron Urbanczyk	Texas Tech University	806-282-7150	aaron.urbanczyk@ttu.edu
50	Kathy Lang	City of Albuquerque	505-848-7174	klang@cabq.gov
51	Scott Bulgrin	Pueblo of Sandia	505 771-5081	sbulgrin@sandiapueblo.nsn.us
52				
53				
54				
55				
56				
57				
58				
59				
60				
61				
62				

MEETING SIGN-IN SHEET

Project: Rio Grande Silvery Minnow Population Monitoring Workshop

Meeting Date: Wednesday, December 9, 2015

Facilitator: Wayne Hubert

Place/Room: Isleta Resort, Seminar Meeting Room

	Name	Organization	Phone	E-Mail
1	Matt Cusack	Atkins	919-431-5255	Matt.cusack@atkinsglobal.com
2	Michael Porter	USACE	505 342-3264	michael.d.porter@usace.army.mil
	Gary C White	CSU/ASIR	970 4826829	Gary.white@ColoState.edu
3	BOB HUGHES	AOI/OSU	208 354 2632	HUGHES.BOB@AMNISOPES.COM
4	Rich Valdez	SWCA/NMISC	435 752-9606	Valdezra@aol.com
5	Mark McKinstry	BOR	801 573-1161	mmckinstry@usbr.gov
6	Mike Marcus	APA	505 379-6891	mdmenv@gmail.com
7	Robert Dudley	ASIR/UNM	505-247-9337	robert_dudley@asirllc.com
8	Scott Bulgrin	Pueblo of Sandia	505 771-5081	sbulgrin@sandiapueblo.nsn.us
9	Rick Billings	ABCWUA	505 259-0535	rbillings@abcwua.org
10	THOMAS ARCHDEACON	USFWS	505 342-9900 x105	thomas_archdeacon@fws.gov
11	Bill Pine	MRGCD/Univ FL	352 2251443	floridapines@gmail.com
12	Kathy Lang	City of Albuquerque	505 848-7174	Klang@cabq.gov
13	Grace Haggerty	New Mexico ISC	505 383 4042	grace.haggerty@state.nm.us
14	Mary Fabrizio	VIMS	804 684.7308	mfabrizio@vims.edu
15	Wayne Hubert	facilitator	307-760-8723	whubert@uwyo.edu
16				
17				
18				

	Name	Organization	Phone	E-Mail
19	Jen Bachus	BOR	505/462-3596	jbachus@usbr.gov
20	Dave Campbell	FWS	505-761-4745	david_campbell@FWS.GOV
21	Eric Gonzales	SWCA/GMISC	517 2858147	EGonzales@SWCA.com
22	Brian Hobbs	BOR	505 462 3564	bhobbs@usbr.gov
23	Justin Reale	USACE	505-342-3138	justin.k.reale@usace.army.mil
24	Wally Murphy	USFWS	505-761-4781	wally_murphy@FWS.GOV
25	Dana Price	USACE	505-342-3378	dana.m.price@usace.army.mil
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

	Name	Organization	Phone	E-Mail
41	Steven Platania	ASIR	5052477337	platania@unm.edu
42	TOM SINCLAIR	USFWS	505-321-9230	thomas_sinclair@fws.gov
43	JASON E. DAVIS	USFWS	505-342-9900	JASON_E_DAVIS@fws.gov
44	Joel D. Lusk	USFWS	505 761-4709	joel_lusk@fws.gov
45	Steven Courtney	WES	5052781161	SPCOURTNEY?@gmail.com
46	Gene Wilde	TTU	806 8340265	gene.wilde@ttu.edu
47	Aaron Urbanczyk	Texas Tech	806-282-7150	aaron.urbanczyk@ttu.edu
48	Ryan Vazquez	Texas Tech	806-834-4987	ryan.r.vazquez@ttu.edu
49	Malia Volke	NMDGF	505-476-8160	malia.volke@state.nm.us
50	Chuck Hayes	NMDGF	505-476-8114	chuck.hayes@state.nm.us
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				
61				
62				

Meeting Sign-In Sheet

Project: Rio Grande Silvery Minnow Population Monitoring Workshop	Meeting Date: Thursday, December 10, 2015
Facilitator: Wayne Hubert	Place/Room: Isleta Resort, Seminar Meeting Room

	Name	Organization	Phone	E-Mail
1	Matt Cusack	Atkins	919-431-5255	Matt.cusack@atkinsglobal.com
2	Jot Janett	APA	505-620-1134	jj@jjwater.info
	Matt Schmader	City of Albuq	(505) 452-5200	mschmader@cabq.gov
3	DAVID PROPST	UNM	505.243.0853	tiuroga@comcast.net
4	Joel D. Lusk	USFWS	505 761 4709	joel_lusk@fws.gov
5	Wally Murphy	USFWS	505 761 4781	wally_murphy@fws.gov
6	Jen Bachus	BOR	505/462-3596	jbachus@usbr.gov
7	Judson Sechrist	BOR	505-462 3601	jsechrist@usbr.gov
8	Frank Chaves	Pueblo of Sandia	505-771-5102	frchaves@sandiapueblo.nsn.us
9	WALT KUHN	TETRA TECH	505 881-3188	WALT.KUHN@TETRATECH.COM
10	Alaina Pershall	Tetra Tech	(505) 264-9749	Alaina.Pershall@tetratech.com
11	Jim Wilber	Reclamation	505 462-3551	jwilber@usbr.gov
12	Brent Esplin	Reclamation	801 524.3304	besplin@usbr.gov
13	JENNIFER FALER	"	505 462-3541	jfaler@usbr.gov
14	Brent Rhees	"	801 524-3600	brhees@usbr.gov
15	Kris Schafer	USACE	505 342-3201	kristopher.t.schafer@usace.army.mil
16	Justin Reale	USACE	505-342-3138	justin.k.reale@usace.army.mil
17	Ryan Vazquez	Texas Tech University	806 834 4987	ryan.r.vazquez@ttu.edu
18	Brian Hobbs	BOR	505 462 3564	bhobbs@usbr.gov

	Name	Organization	Phone	E-Mail
41	David Gensler	MRGCD	2470234	dgensler@mrgcd.com
42	Grace Haggerty	NMISC	3834042	grace.haggerty@state.nm.us
43	Mike Hamman	MRGCD	247-0234	mikeh@mrgcd.us
44	Steven Platania	ASIR	247-9337	platania@unm.edu
45	Tom Sinclair	USFWS	321-9130	thomas_sinclair@fws.gov
46	Jason E. Davis	USFWS	342-9900	Jason_E_Davis@fws.gov
47	Todd Caplan	GeoSystems Analysis	980 0336	todd@gsanalysis.com
48	Gene Wilde	TTU	806 834 0265	gene.wilde@ttu.edu
49	Aaron Urbanczyk	TTU	806-282-7150	aaron.urbanczyk@ttu.edu
50	Dana Price	USACE	505-342-3378	dana.m.price@usace.army.mil
51	Julie Alcon	USACE	505-342-3281	julie.a.alcon@usace.army.mil
52	Ann Demint	BOR	505-462-3654	ademint@usbr.gov
53	Jim Brooks	Self	505 331 5926	arroyodejaime@gmail.com
54	Dave Campbell	FWS	505-761-4745	dave_campbell@fws.gov
55	Mary Fabrizio	VIMS	804.684.7308	mfabrizio@vims.edu
56	Bob Hughes	AOI	208 354 2632	HUGHES.BOB@AMNIISOPES.COM
57	Wayne Hubert	facilitator	307-760-8723	whubert@uwyo.edu
58				
59				
60				
61				
62				

12/10/2015

	Name	Organization	Phone	E-Mail
19	Michael Porter	USACE		
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Appendix F
Recorded Notes during the Workshop
(Days 1 and 2)

Concurrence Points Notes from the Rio Grande Silvery Minnow Workshop
Wayne Hubert, Facilitator
Matt Cusack, Data Recorder

1. Is the CPUE index appropriate for monitoring the RGSM in the Middle Rio Grande?
    a. (Fabrizio): Regarding the seine nets themselves, has there been any modification to the gear over time? Not how it was deployed, but the actual gear itself
        i. (Dudley): The gear has remained true in its general concept. Have switched manufacturers. The number of floats and dimensions have remained constant. The adult seines have switched manufacturers, but the juvenile seines have been provided by the same manufacturer over the life of the program.
    b. (Hubert): Has the lead line changed over time?
        i. Dudley: Continued to use heavily weighted (double weighted) to make sure that the bottom of the net stays in contact with the river substrate
    c. Fabrizio: Please clarify how the seine is deployed (upstream to downstream)
        i. Dudley: Coming from the East Coast, It is unusual to go downstream (with flow), but the technique has remained consistent for this program. We have a person along the shoreline (right at shore) that moves down more slowly than the person on the downstream end of the seine. Both folks will move somewhat quickly but will be spaced apart. The downstream end of the seine then sweeps into the shoreline at the end of the transect. For mesohabitats like pools and backwaters, this technique is also used.
        ii. Dudley: For runs or other open water, the net is lifted with the lead being lifted first rather than beaching.
        iii. Seine hauls are most commonly performed at knee depth, occasionally thigh depth. Typically avoid deeper water on the outside edge of the river with the fastest flow.
        iv. Archdeacon:
            1. Well over half (50-80%) of RGSM in a depletion sampling are collected in the first pass
            2. Believes this to be an effective method
    d. Fabrizio: Would you say that the downstream sampling is common method (the regionally appropriate) for sampling in the Rio Grande
        i. Dudley: This is a common method in New Mexico, used by numerous agencies
        ii. Dudley: In the literature and more broadly, this is common in southwest in dynamic sand bed systems.
        iii. Dudley: Going upstream would make it difficult to access some of the mesohabitats
        iv. Archdeacon: Agrees that southwest sampling is different than the east coast. USFWS uses the same protocol
        v. Porter: Agrees that this sampling type is used by the USACE in the Rio Grande
    e. Hubert: If a snag or obstacle is encountered, are the data still used?
        i. Dudley: No, the sample is discarded
    f. Fabrizio: What is the quality assurance of the seine deployment? Do you have third party observers to make sure that techniques are deployed in the manner in which they are described?
        i. Dudley: Occasionally folks from the BOR or USFWS have come out and observed or participated in sampling efforts. Not a formal oversight or quality assurance program. There is self-imposed quality assurance, with experience longevity of sampling personnel. Between 3 crew leaders, one is always present. A crew leader has a minimum of 10 years sampling experience with this sampling approach. Goal is consistent sampling protocols.
    g. Fabrizio: Are the different agencies generally satisfied with this sampling methodology

- i. Archdeacon: Yes
- ii. McKinstry: We don't administer the sampling contract. No controversy with the protocol, only the data interpretation. The approach needs to be defensible.
- iii. Valdez: The manner in which a seine is drawn is not the issue, but rather how the data that are collected with the seine are interpreted.
- iv. Porter: Within the context of the program, the sampling methodology appears to be meeting the objectives. Over the last 10 years, there has been some new opportunities to refine the methods, as well as the analysis.

h. Hughes: What studies were done initially to determine the length of the sites and the size of the gear?
- i. Dudley: Some of those decisions pre-date me. The length of the sites, within a 200m reach of river you would encounter the full suite of mesohabitats that would be representative of those found throughout that section of the river. Not necessarily every single mesohabitat, but representative. A massive inventory was undertaken in the late 1980s, Dr. Dudley believes that the length recommendation came from that work.
- ii. Dudley: As per the size of the gear, is similar to the gear used by other Rio Grande researchers. Tried to use the standard gear (seine size)

i. Hughes: Sacrifice the width of the seine in order to move quickly in the water?
- i. Dudley: Precisely

j. Hubert: How is the distance that the seine is pulled measure
- i. Dudley: Rolled out metric tape held by the third crew member (data recorder). They are in charge of the fish, making sure that the collected fish cannot escape.

k. Hubert: Two different gears are used. The index of abundance…are the data from each gear combined into the same index?
- i. Dudley: No. In the fall sampling (October), the spawning period is over by then
- ii. Hubert: I don't see a distinction between the larval nets or the larger nets?
    1. Dudley: The data presentation used only the larger nets. October data are only using the larger nets.
- iii. Hubert: When I looked at the data, it looks like the data from months other than October are combined into one index
    1. Dudley: For months other than October, that is correct.

l. Fabrizio: It appears that most of the data comes from age 0 fish. I would like to hear some comments about how efficient the seine might be for other age classes, specifically for the size of the seine and the deployment methods.
- i. Dudley: The remarkable thing about this species is that is has already reach a 60mm standard length by the October sampling event. Into the next year growth is minimal compared to the first year growth.

m. Fabrizio: Historically, I believe I read that the RGSM might live to 3 or 5 years. Are there observations on these older fish in the same survey data?
- i. Dudley: There was an age and growth study that specifically looked at otoliths and scales to age the fish. As you alluded to, most captured fish were age 0. There is a specific interval of length that is correlated with age. In the field, we find fish that are dominated by the first two year classes.

- ii. Porter: Mary has hit on one of the key questions with the monitoring methods. How effectively are we sampling the entire population with regards to size and age. We occasionally see much larger fish, with much larger numbers of older age classes spawning into the floodplain where the numbers are not supported by the in channel sampling.
- iii. Archdeacon: We don't have the exact numbers, but we do release hatchery fish. Only two recaptured to date have been age 2, with the remainder being age 1 recapture (from fall age 0 release).
- iv. Dudley: Have put together information regarding the frequency distribution of the different age classes, found that the overwhelming majority were age 0 with lesser frequency age 1 and 2 fish.

n. Hubert: With the exception of the October data that are used for population modeling, how are the data from the other months being utilized?
- i. Porter: Two examples
  1. a) Population viability analysis which began in 2008. Monthly sampling data are very useful for general trends.
  2. B) The second example is for 5 years the USACE did an experiment manipulating the hydrology from the upstream dam. We used those population data to monitor how the hydrograph occupied the floodplain and how the RGSM responded with spawning behavior. There have been some insights from these data, and we are trying to figure out how to handle the data in the "bad years"
- ii. Archdeacon: USFWS would use these non-October data for
  1. permits and calculating incidental take.
  2. For calculating hatchery augmentation

o. Valdez: Has there been an attempt to calculate capture probability?

p. Valdez: Back to the fundamental question, is the CPUE the most appropriate index? Are there other ways to measure the abundance and the status of this fish? Is this the only way to do it?
- i. Fyke nets in the floodplain edge during high flow events
- ii. Are there other methods or techniques that could be used as an alternative to the CPUE index (seining)?

q. Marcus: The catchability index is a pressing question. The RGSM is a schooling fish. That is accepted from the literature. Schooling fish require different sampling than regularly distributed individuals. The literature does not currently provide adequate recognition to this feature. Clumped distribution require different sampling methods. I also believe that there is risk of disturbance that can cause the dispersion of the species.
- i. Archdeacon: In Dr. Dudley's presentation, he described some other sampling methods (elimination sampling using electrofishing). While I personally haven't used any different methods, the data appear to be consistent between different sampling programs using the seining methodology. The trends coming from the population monitoring match the results from different crews and different studies.

r. Archdeacon: Are there any data that suggest that the seining method is not adequate, that would encourage further re-evaluation of the sampling method.
- i. Dudley: The enclosure methods did match the trends found from population monitoring. The enclosure method did not find majorly different density than the seining. Request to see

a paper or review that suggests that tens of thousands of RGSM have been documented from a single pool that was discussed by Mike Marcus?

- ii. Porter: Electofishing, fyke nets, and seining methods have been compared. Also research into habitat use, which uses a dual seining method. The dual seining method uses a mobile seine (similar to Dudley) with a bag seine as a backstop (downstream end). Four crew members pull the mobile seine towards the bag seine, then the lead weights are lifted in a manner that is overlapping. The data are kept separate from each seine type.
  - 1. Hughes: The results?
    - a. Porter: This is the first year with good reproduction to test the results. Each seine haul typically gets about 60% catch, with the bag seine getting the remainder for that run. Hasn't had a chance to look at the trends specific to the RGSM.

- s. Archdeacon: If we have different gears, there would be varying detection probabilities at different sites at different years, yet the data show the same trends. Are the data showing changes in detection probability, or different years?
  - i. Pines: Table 5 of the 2011 of Rio Grande Population Estimate report and Appendix G have capture probability estimates recorded for the depletion samples.
- t. Hughes: We are really not answering Question 01. I would say "Yes". There may be other methods that could augment or be considered. Are there other indices?
  - i. Total Population Abundance
  - ii. Valdez: We are dealing with a very small, short lived species. I am not disputing the CPUE index, but wondering if there are other options.
    - 1. White: Clearly an r-selected species. From the population estimation data, sometimes there are two orders of magnitude changes. Monitoring population is a waste of time due to these changes. Instead, managing habitat using an occupancy model
      - a. Valdez: is the occupancy model calculation being done on the seine haul unit basis or on the pool unit basis by site? The seine haul is not calculated on the individual haul, rather it is calculated on the site.
      - b. White: Occupancy data are calculated on time, not space at the site basis and require four visits. Current data are one visit per month.
      - c. Valdez: Occupancy models are intended to define whether a fish occupies a specific mesohabitat.
- u. Hubert: Are the data obtained from the current program compatible with occupancy modeling?-
  - i. White: NO, multiple visits are required.
    - 1. Hughes: How many visits, and how far apart?
    - 2. White: We should start with four, and then could design an optimal study. Four gets an estimate of the detection probability.
- v. LUNCH BREAK Until 1:30pm
- w. Valdez: Closed the discussion before lunch discussing occupancy modeling. Would like to hear more discussion.
  - i. Hubert: Should we explore a different index, and what would be required to initiate this new approach.

1. White: Occupancy is not an index of presence. Is not estimating populations. Requires multiple visits in the fall. Site is assumed closed, has to be closed during all site visits.
2. Valdez: Have we done a power analysis
    a. White: No but the data are available to do so

x. McKinstry: What are we doing with this? We come up with a population estimate, that is usually a number. He is not sure how these estimates are being used. What do we need to get in order to satisfy the regulatory agencies. Since BOR isn't the decision maker, want to make sure that the correct information is being collected.

- i. Fabrizio: That is a very important question, and as an external panel member that is a very important question. It would help the panel to know what the criteria are for restoring or delisting the species.
- ii. Valdez: Don't think there is a single answer. Each stakeholder has a different view point. The overall purpose is to look at the status and the trends of the fish over time and space. Can we follow the abundance and status over time and space using the CPUE index?
- iii. Fabrizio: Needs more clarity on this answer. Would like to know up front. If monitoring status and trends, how do you measure success/failure?
- iv. McKinstry: As a management agency, how can we tell if what we are doing is restoring or allowing further degradation of the managed species.
- v. Hubert: The overall answer depends on the question, as well as the spatial scale of the question.
- vi. Valdez: The question may not be when we have reached a certain point. Can we in fact make that determination? If we want to monitor a specific management action and detect a 10-percent change in the population. We have to look at probability of detection, may not have this amount of sensitivity in the data. It is important and critical to look at the robustness of this monitoring program and whether the detection probability can be calculated.
- vii. Archdeacon: There are recovery criteria for the RGSM. To prevent jeopardy, there is a CPUE of 5 for 5 consecutive years. Confirm against recovery plan.
    1. Updated 12/21/2015: Recovery Criterion 2-A-1. Using the standard sampling protocol (Appendix E), and sampling at a minimum of 20 sites distributed throughout the middle Rio Grande in New Mexico, document for at least 5 consecutive years, an October catch per unit effort (CPUE) from all monitoring sites within each reach of > 5 fish/100 m2 .
- viii. Pine: Suggest a clarifying question: Is CPUE index appropriate for detecting a response related to the recovery goal?
- ix. Hubert: The monitoring program is one way of looking at the question of recovery
- x. Pine: Monitoring programs often have numerous objectives. Different stakeholders have different interests in the monitoring program. The question as phrased is too open ended and therefore this panel cannot assess.
- xi. Porter: CPUE has been informative on years with strong seasonal flows. For large scale hydrograph, we can tell if we "got everything right." But if we didn't get everything right, we may not detect the response. Can't tease apart the contributing components (magnitude, duration, habitat components)

    xii. Dudley: Mixture modeling in place can weigh the different factors. These factors can be entered into the model and if they are floated to the top will be subjected to the same scientific rigor of anything else that is evaluated.
    xiii. Pine: Fundamentally, the response variable is still CPUE. You can include flow metrics, or combinations of several metrics (seasonality). What is the relationship between CPUE and abundance? What is the detection threshold? Can't separate capture probability and abundance.
    xiv. White: Can't detect variability in individual capture probabilities across years. One of the reasons is that you can't estimate capture probabilities when there are no fish due to lack of water.
    xv. Pine: You can detect order of magnitude responses. If a finer response is needed, then there is a need to address the confounding issue between capture probabilities and abundance.
    xvi. Dudley: Can we differentiate between years using a 95% confidence interval in CPUE estimates. Those intervals don't span an order of magnitude. They are less than that, but you have to evaluate with perspective relative to magnitude of change across years.
    xvii. Valdez: If you take these data and run a power analysis…he calculates a change detection of 60%. Is this good enough for managers?
        1. Hubert: Is a 60% change in detection equivalent to a 60% in abundance?
        2. White: Capture probabilities don't vary much across years. So a 60% variability in detection is
    xviii. Pine: Occupancy models have potential in this situation, which makes it a good fit for this situation.

y. Pine: Before we discuss alternative frameworks. A CPUE index is appropriate if we understand the difference between capture probability and abundance. Is catchability constant across space and time. During the population estimation efforts that suggest different catchability in mesohabitat and time. Do the available approaches (Dr. White)
    i. Is there a graph available that shows the estimated trends in GLM overlain on catchability through time?
        1. White: We were using removal estimators. Seldom removed enough fish to trigger successive hauls. Pooling data across years, but did keep data straight by mesohabitat type. There were differences between mesohabitats. Overall, there is a weakness of data.
        2. Pine: Referring to Table 5 and Table G1 from the 2011 report. Both have capture probabilities by mesohabitat, and the other one is detection probabilities by day from the passes. Has Day 1-4, year, and age. Believes that these are capture probabilities from occupancy modeling. His question is whether White has looked at GLM standardization of CPUE and if those match capture probability estimates in abundance.
        3. White: N under CPUE data are fish caught on a site. In order to get population estimation data (Q) we have to correct for 20 sites rather than 1,120 sites.
    ii. Pine: In the mixture model you use abundance, not CPUE. Have to assume catchability is the same across time. For CPUE to relate to N, Catchability has to be constant. Pop Mon data do appear to have catchability vary over time.
    iii. Pine: Does the mixture model include a detection function?

1. White: No

iv. Pine: Does detection probability change over time?

1. White: Don't know. Two different detection probabilities. For the individual detection probability, we don't know. Not enough data for any one year. For the occupancy model, the detection probabilities vary by year for a logical reason (density varies by year).
2. Valdez: For population estimation in Program Mark, was capture probability determined from each pass. (No from White). It was set equal in Program Mark.
3. White: The weakness of the PopMon data was p.
4. Archdeacon: There is a regression of raw CPUE vs population estimate. There is not a lot of data to it, but the r-squared is .95. He believes that information has been provided to the experts.

z. Hughes: Believes that CPUE alone is not sufficient to address the objectives raised by the Program.

2. Are the monitoring plan and sampling design appropriate for tracking the status and trend of the RGSM in the Middle Rio Grande?
    a. Hubert: When we discuss the "monitoring plan" what are we specifically referring to? Does that have a precise definition or specific document? Or is it the recovery plan or something else?
        i. Dudley: There is a document called "the monitoring plan" that was published by the Collaborative Program in 2006. As far as the guidance that he follows, there were changes in 2006 in terms of the overall plan, the frequency of sampling, etc. They were codified into the 2006 document and released as RFPs.
        ii. Valdez: The annual reports on population monitoring there is a succinct description of what is being done at the time. He refers to these documents when discussing the monitoring plan.
    b. Hughes: What is the rationale for the numbers of each mesohabitat sampled at each site?
        i. Dudley: At a particular sampling site, the total number of all mesohabitats is 20. Why do we pick 20? We sample over 200m and through he initial studies that they have done found that they could capture all of the different variability present within that reach for analysis. They wanted to have every mesohabitat represented by at least two examples. Runs typically comprise 80% of the available habitat, but they decided against sampling by proportion of site, but rather representative of those types available.
        ii. Fabrizio: Was there any analysis completed regarding how the proportion of the mesohabitats changed from year to year? Is there some indication of change since the river is very dynamic.
            1. Dudley: The best information that they have for that came from the Population Estimation work because the mesohabitats were mapped to the nearest 10cm. The BOR has the full GIS database delivered in 2012.
            2. Hughes: Although mesohabitats move, were they equally represented through the site? If you have 2 debris piles would they persist across years and flows?
                a. Dudley: The stability of the site (incised vs braided) would impact whether the same types of mesohabitats are available year to year.
        iii. Hughes: Multiple seine hauls for each mesohabitat?
            1. Dudley: Correct
            2. Hughes: Up to 5?
                a. Dudley: Depends on the mesohabitat. For habitats like runs there were a maximum of 4 hauls. For backwater maximum of 2. For shoreline runs, max would be 16 leaving 4 for shoreline runs?
        iv. Hughes: When you ran into a dry site, how do you handle those data? No data?
            1. Dudley: Assign 0, so you still have twenty sites for each month.
            2. White: No detection probability issue, there is no distinction. Just more sure that there are no fish.
    c. Fabrizio: When designing monitoring programs, it is always difficult to design for multiple species. Can you tell me what would you do differently is designing only for the silvery minnow.
        i. Dudley: The inception of the program was specifically targeting small bodied fish. Since small bodied cyprinids were the focus, the design was geared at picking up any low frequency or rare species.

    ii. Dudley: The reason to keep things the same is the long record of consistently collected data. The population estimate study allowed him the chance to design, which allowed for site mesohabitat randomization. If I was to redesign the study today, I would focus on these types of variables for the PopMon. Don't know that we could do too much more without increasing the scope of the project. A more robust way of increasing the sites or mesohabitats sampled would likely be the outcome.
    iii. Porter: Spend some time looking at experiments to calibrate catchability. Look at flow velocities, depths, size classes of fish. Try and identify the catchability value for those variables. Probably also include substrates. Fairly rigorous evaluation to determine any changes to the design.

d. Fabrizio: Age 0 fish are a big component of your CPUE data. How important is it to delineate nursery or spawning areas and sample that adequately. Does the current design allow for that?
    i. Dudley: The current design focuses on month to month changes. New born fish have a fast growth rate and spend weeks (not months) in those nursery habitats. Those habitats are ephemeral at best, so wouldn't work for annual sampling. They spend most of the year with the remainder of the population.

e. Hughes: Seems like the focus is on the October numbers. Why not sample more sites with more effort (bigger and longer) and drop the other sampling?
    i. Dudley: Sampling occurs during the irrigation season because the population changes so rapidly, particularly during droughts, that they receive numerous requests for real time updates for population estimates. In 2006, monthly sampling was reduced to bi-monthly in the winter and monthly in the summer.
    ii. Dudley: Take from one and give to the other is a good question, but one that others might need to support his answer. When we hit those low numbers it would be nice to have more sampling sites.

f. Hubert: Refugia. The 20 sites are not necessarily identifying the refugia? Has there been a low flow effort to identify, map, and/or monitor the fish within those areas?
    i. Archdeacon: The USFWS has variable sites (besides the Dudley fixed sites) and have some sites below diversion dams that sample some of those refugia.

g. Hubert: Are there certain locations that year after year can be found to have potential refugia?
    i. Archdeacon: The diversion dams and the entire Albuquerque reach have reliable water year over year.

h. Hubert: How do the USFWS efforts and the Collaborative Monitoring program integrated?
    i. Archdeacon: The monitoring that the USFWS does includes sampling on tribal lands, which the USFWS does not share due to sensitivities. Looked to mirror similar methodologies, but in the past haven't shared all data.
        1. Hubert: There is potential for additional sites to look at trends through data sharing
        2. Archdeacon: Through salvage and the USFWS efforts the fish densities do mirror the PopMon estimates reported by Dudley

i. Hughes: Are there sufficient deep water sites that could use a boat and a trawl? It is a different habitat that isn't being sampled in October
    i. Dudley: In October flows are moderate to low, so they don't often encounter that situation. Typically plan sampling to evade that situation by watching the hydrographs so that all sites can be sampled through wading. One caveat is that during the higher flows, they don't have

the cobble lined bank which requires the ASIR team to be more selective when choosing mesohabitats.

- ii. Bulgrin: There are electrofishing from the BOR from all three reaches. Sampling is usually performed in the winter.
    1. Hubert: Are these data publicly available?
    2. Bulgrin: Yes
- iii. Hubert: Are these data integrated into population monitoring trends?
    1. Dudley: Is aware of these data but haven't integrated them into their data.
    2. Hubert: Probably a need for some data integration across agencies

j. Fabrizio: Wondering if there is any evidence that the RGSM are using refugia or habitats that are not routinely sampled. Is there a chance that the fish could be heavily using these other areas that fall outside of the current scope of the monitoring program.

- i. Bulgrin: Probably yes. There are several habitat construction projects that have been undertaken by several agencies that have been known to attract the RGSM. Due to time and budget constraints, these areas are not monitored on a regular basis.
- ii. Porter: USACE is looking at those mesohabitats and are starting to get some data related to backwater vs main channel habitat
- iii. Dudley: When the population estimate study was completed, the random sites and random mesohabitats provided an evaluation of densities that would not suggest that they would have the unusually high abundance that were not being captured by the population monitoring.
    1. Fabrizio: Clarification on the areas that have backwaters? Are there more backwaters in areas being restored? Are natural or restored backwaters more prevalent? Is the physical structure different between restored and natural backwaters?
    2. Porter: 2005 floods changed the available backwaters significantly. Trying to monitor those backwater areas that are associated with USACE restoration projects.
        - a. Hughes: Those constructed systems, how long do they persist naturally?
            - i. Porter: Seen the full spectrum of restored features that were gone the next year. The longevity of restored backwaters is comparable to naturally occurring backwaters. USACE is learning a lot about how to design

k. Valdez: (Comment) Mike Marcus commented that the RGSM is a clumping species (Question) Why are the mesohabitats sampled in the proportion that they are when three specific mesohabitats hold 90% of the fish? Why is the sampling not distributed to take advantage of the contagious distribution of the species.

- i. Dudley: Debris piles are common in some river systems and less common in others. He would characterize the Rio Grande as a system where debris piles are not common. They do sample them when they are encountered. They do agree that backwaters and pools do have higher densities in those habitats. They don't target those areas more heavily because they try to maintain consistency as much as possible. If the site is diverse, then half of the samples will be from those sites. The main reason is that they didn't want to get into "chasing fish" so add some standardization. They are striving to have consistency.

ii. Hubert: Do you think that your capture efficiency is higher in backwaters than in shoreline runs?
    1. Dudley: Yes, I do think so

iii. Valdez: Heard that these are 0 inflated data this morning. In other monitoring for other species, there is often a stratification that provide the least variability in the index.

iv. Marcus: Say that we do have a schooling population of a small bodied fish in a large river system. (White) how would you design a monitoring program that would capture the clumped distribution of these fish?
    1. White: How big are the schools?
    2. Marcus: Where does it make a difference?
    3. White: We are sampling a 200m reach
    4. Marcus: Assume we have several hundred to a few thousand fish that are sensitive to disturbance.
    5. White: Adaptive sampling, but there is a challenge that the fish could be scared away from the sampling in place. Doesn't foresee the clumping as an issue that is not being captured by Dudley methods.
        a. Dudley: Turbidity levels allow capture of fish that suggests that evasion is not a big issue in the success of fish collections.
    6. White: The biggest variability is site to site. How do you identify the clump? Doesn't believe that the schools are that large (hundreds of meters) that we are not getting a representative sample from? The best way to reduce site to site variability is to sample more that 20 sites.
        a. Pine: Would like to tie this back to Main Question 1. Given the high variability between the sites, adding more sites may reduce the variability. Is reducing the variability going to make detecting CPUE changes more likely.
        b. White: If you collect four times the samples you half the variance. Those results are in one of the reports on population estimation.
        c. White: We are never going to get to the point where a finite population correction is going to help. Finite population correction is not a fix.
        d. Archdeacon: Agree with White that more sites are required to reduce site to site variability. Need to identify what the confidence interval needs to be, since narrowing the confidence intervals would require a lot of additional personnel effort. Stressing that the sampling resolution needs to match the management actions.

    7. Hughes: If you are sampling a mesohabitat and are scaring fish, could enclosure sampling reduce the risk of losing fish?
        a. White: When we did the population estimation work, we did enclosure sampling and electroshocking. Mapped out the mesohabitats before sampling, then did gridded sampling. It wasn't detection probabilities that caused the variability.
    8. Hughes: What causes the site to site variation
        a. Dudley: Physical barriers and spatial variability. There are upstream to downstream differences that we see across years even with constant

augmentation. More young fish lower in the system. Habitat within the reach is another factor. Fish may be in the area but are more transitory.

- v. Valdez: Instead of going to 20 sites and taking 20 hauls during the month of October, what if we stratify the sampling by mesohabitat type and sample only those habitat types where one would expect the largest number of fish (pools, backwaters, debris piles). Then do encounter type sampling on a predetermined schedule. Looking at general sampling design to address the issue of 0 inflated data and sample/site variability.
    1. Hughes: I call that point design. So you would have 400 points.
    2. Valdez: Not a fixed location design, yes.

l. Fabrizio: Not a lot of analysis of water chemistry covariates.
- i. Why are we not measuring water velocity at the level of mesohabitat
    1. Dudley: It is difficult, but possible. In the past they have measured discharge at the site. Velocity, depths, and substrates could be added but add time to the sampling. Typically have a rapid turnaround time on the seine hauls, and if we added additional data it would slow the progress rates. Having enough data for analysis is another factor limiting the usefulness of these data beyond a snapshot.
    2. Porter: For habitat restoration monitoring the USACE collects depth and velocity and is seeking to get enough data to evaluate fish preference.
- ii. Are the water quality measures not valuable?
    1. Dudley: Those are snapshot factors and don't have the robustness in order to consider them in the covariant analysis. That is main reason they are not incorporated. If you set up water quality monitoring station then you could have better established patterns for including in analyses.
    2. Porter: Generally agree with Dudley assessment that the data are a snapshot and not robust enough for inclusion in the analysis.
- iii. Hughes: If you don't use the data, why collect them?
    1. Dudley: We have asked the same question and do not have a good answer. Tradition. There are times when the data have been informative during freak events. For instance there was a series of fires in Los Alamos areas where ash flows were reaching the river. Were able to gather anecdotal water quality data during the ash flows and correlating them to fish kills.
    2. Dudley: Main concern is critically low DO levels. Haven't seen that very often, but continued monitoring assists in making those determination when the condition arises.
    3. Archdeacon: The USFWS has stopped taking some of these measurements.
- iv. Marcus: Considering the water chemistry data are not that valuable, but the flow data could be…is there a tradeoff to swap those data? Could you trade chemistry for flow?
    1. Dudley: Those data would be more valuable, but the main difference is the amount of time required to collect the data is not the same. Water quality takes <5 minutes, but the flow could take upwards of an hour.
- v. Valdez: Observation. Sees a great value in these data related to the demographics of the species. Still asking the question whether the group is resolved that the sampling design isn't going to do a lot of good without recommending changes.

1. Hubert: Prioritizing catch curves could be useful information. Are there more things that could be done with data or with small modifications to the existing program could be derived and be useful?
2. Valdez: Growth rate or catch curves

vi. Valdez: Is the group satisfied with the current sampling design?

1. Archdeacon: Regardless of the method used, sample size is always going to become an issue. Sample size may not provide the resolution to support management decision making. There are plenty of things that could be inherently more precise.
2. Pine: What is the resolution that the agencies require for their management actions?
    a. What amount of change would like to see detected to support or evaluate your management actions.
    b. White: 2012 and 2014 detected no fish at the 20 sites. What management decisions were made?
        i. Archdeacon: the USFWS would stock more fish
        ii. McKinstry: Might be a jeopardy situation where locking down irrigation may be required. Those are the things that the agencies need to do.
        iii. White: Interesting that these data become available at the tail end of the irrigation season. What is the time lag?
            1. Dudley: First week of each month. Rapid turnaround of a days to a week for critical decision making. Final report available to public six weeks after sampling.
        iv. Billings: The management staff didn't take action in 2012 or 2014. Would look to the regulators to require changes or adaptive management. There hasn't been an update of the water managers. The following management strategies could be tied to the population monitoring efforts with some clear guidance on how to evaluate the need. If there aren't good monitoring data to support the decisions, then what is the point?
            1. Spring spawn (natural or engineered)
            2. Minimum flows using water available
            3. Habitat restoration
            4. Fish augmentation
        v. Valdez: What do 0s in this monitoring program mean? In other types of monitoring, 0s could mean very serious population decline. Is there a need to enhance the sensitivity of the monitoring program when the numbers get critically low?
            1. Hubert: 0s could mean there is low water. If you have 0s with wetted habitat that could be an indication of something quite different. Or, maybe you aren't sampling in the right places or didn't detect them.
        vi. Marcus: When the 0s were identified in 2012 and 2014, did ASIR notify the managers to facilitate a management action?

1. Dudley: Don't report immediately on years where there is not a crisis. In drought years it is an expected telephone call or communication to make the managers aware and to ensure that information is disseminated.

vii. Pine: Are these 0s consecutive? What is the context behind the 0s

1. Dudley: Of the 400 seine hauls that were collected, no silvery minnow were collected. It is a 0 across every haul at every site for October. What does that mean?
2. Pine: Site occupancy, when does a 0 mean something. If 80% of the sites are occupied, then the 0s should be interpreted against the other data that have already been collected and interpreted.
    a. Dudley: Did not have 0s during those years, so you cannot directly correlate those data.

c. Hubert: Monthly sampling leading up to October can clarify the results of the October sampling. The summer monitoring could be valuable for management decisions.

vii. Valdez: What other demographic parameters can be taken or teased from the CPUE data?

viii. Hughes: How are the agencies looking 100 years ahead when the drought conditions are expected to be more common

1. Archdeacon: This is a heavily augmented population. Have tried to coordinate with ASIR to avoid stocking immediately sampled.
    a. Hughes: Are these fish marked? Yes (Archdeacon)
    b. Hughes: Looking at the fitness of the natural population with regards to augmenting?
        i. Archdeacon: There have been genetic bottlenecks, but it hasn't been as severe as other augmentation programs. The wild fish look a lot like the hatchery fish.
        ii. Fabrizio: Have there been studies to examine whether or not the age 0 fish that are considered wild have some hatchery origin to them? Is there a way to tease this out or not?
            1. Archdeacon: We cannot tease that out at this time, but we suspect that the proportion of hatchery to wild fish there almost certainly needs to be a link. On salvage hatchery fish are much more common than wild fish
2. Billings: New water management strategy is coming out in the next spring and will include a lot of climate adaptation management.
3. Hughes: When thinking about the future, we need to think about long reaches for long periods of time that may be without water.

ix. Please expand on the salvage operation

1. Archdeacon: Driving up the river and mapping each reach and relocating them to a perennially wetted section of the river.
    a. Fabrizio: Are there estimates of survival estimates from salvage?
        i. Archdeacon: Maybe older data

        2. Pine: Are the hatchery fish reared from wild eggs
            a. Archdeacon: The eggs are collected from the river, and then those are reared for hatchery augmentation.
    x. Hughes: Are there any fish preserved in alcohol where the genetic analyses could be performed to see how the genetics have changed over the years
        1. Archdeacon: Yes there are data and published reports.

m. Miscellaneous
    i. Porter: Adaptive Management program. Going to look at all levels of native species including the RGSM. Will rely on collaborative partners to do detailed analysis. CPUE and monitoring is going to one aspect of this process, and the results of this process will be very informative to their decision making.
    ii. Fabrizio: Couple of other issues with regards to Question 2.
        1. Stratification: Necessary or desirable? She has taken away from yesterday the reaches are somewhat independent and disconnected, and she would like to hear whether the survey that produces the CPUE estimates might benefit from stratification. If yes, what kind?
            a. Dudley: This has been discussed in the past by ASIR. There are differences across reaches. There is a lack of downstream to upstream connectivity. The issue that was encountered during the original population estimation efforts was the number of sampling units. Stratification across reaches would not produce adequate sample sizes.
            b. White: Population Estimation (not PopMon) did use stratification of the reaches. Did not make sense to change the sites from year to year, so the same sites were used for that effort as the PopMon efforts.
                i. Fabrizio: Was primarily interested in the PopMon efforts to see if stratification by reach if there is benefit
                ii. White: There is that stratification in the data
                iii. Fabrizio: Is that how they are presented?
                iv. White: Sometimes
    iii. Hughes: Do sites display homogenous or heterogeneous distribution of habitat? Is there consistency of habitat (not mesohabitat scale) at the site scale?
        1. Dudley: The answer is highly variable across years depending on the particular site. Some sites that are highly channelized would class as pretty homogenous with little change across time. Those are the narrowest sites. If you change the factors that would be most indicative of how mesohabitats are predicted, it would be channel width. The wider the channel, the more heterogeneous that habitats available within that site. To qualify that, the sampling in October the flows are generally moderate and so they are not dealing with the highest or lowest extremes of the flows. Therefore the variability is not as dramatic during that sampling as occurs during the rest of the year.
        2. Archdeacon: The most channelized areas are the most homogenous. When the river is dry, there are pools that developed from a tree that fell. There are some features that appear to be permanent. Most pools are getting shallower as they fill in. He

can't recall any that are getting larger. There is variability, but there are some mesohabitats that persist year over year.

3. Dudley: These habitats to have a tendency to shift around. Seems to be certain characteristics of each site, despite the individual features that move around within the site. For instance, the way the river carves around a corner, there is going to be a deeper pool. The spatial location may be different, but a pool in that location can be expected.
4. Valdez: Dr. White stated that the greatest variation in the CPUE effort is from site to site. Intra-annual variability (White: yes). Is this because the changes of variability due to the geomorphology or because of how the fish use the site.
    a. White: Inherent differences across sites, but I haven't ever looked at the data in the way.
5. Hubert: 20 fixed sites. Is the variation consistent from year to year. Are some sites always predictably low CPUE vs other sites that are predictively high? Are there known "good sites" and known "poor sites?"
    a. Dudley: We looked at this specifically with the mesohabitat dataset. We did add a covariant for site with the idea being to assess whether there were predictable trends relative to site. It turns out that the data did not support that. Across years, some sites will be high one year relative to other sites, but then may be low relative to other sites in another year. The differences across years do not appear to be based upon the locations of the fixed sites.
    b. White: Some of the years I have run site models. Is there an easy way to factor out variability by site? Simply, no.
        i. Hughes: In my mind that is good
6. Porter: The USGS mesohabitat study look at 15 sites at two different flows, as well as some other studies. What has been missing from those studies is nursey habitat. All of these studies are in-channel studies.

iv. Fabrizio: Question concerning the number of mesohabitats. Some papers were using very fine definition of mesohabitats (lots of habitats within a site), while other papers seemed to group them more. I would be interested in learning whether a finer enumeration of groups of mesohabitats is desired? How coarse of a classification for mesohabitats

1. Dudley: You are correct that over time there has been a change of reducing down to currently 5 mesohabitats. These changes came through conversations with Gary White to focus on what is trying to be evaluated. In the past we made the distinction between main river and side channel, but found that these distinctions clouded the data. You would assume that in a side channel there would be less flow, but found that it was not always apparent in the field. We decided to classify those separately. What was found to be important were the velocities (run vs pool). We ultimately went with the lowest common denominator in terms of habitat classification.
2. White: In trying to do the analysis I wanted smaller number of habitats. With more habitats, many didn't occur at every site. With these five categories, we more commonly have observations of each mesohabitat type across years for each site.

v. Hubert: Would like to refocus back onto the augmentation. Would like clarification regarding the interaction between augmentation

1. With the stocking of the fish, how are they marked?
    a. Archdeacon: Visible tags that should be distinguishable. As long as the researcher is looking for it, should be identifiable
    b. Pine: Body location, colors that are used
        i. Arch: Predorsal (left or right). Have used six colors. Difficult to use all six colors in the same year. Several colors are similar. Try to avoid using more than 3 colors in one year.
        ii. Pine: In any one year, you could use from 1-3 colors. Do those colors represent any information (reach, when stocking tool place)
        iii. Archdeacon: Yes, for several years color indicated reach. For the past 2-3 years, the colors are different hatchery origin.
        iv. Pine: Using visual tags, can be difficult to discern the different colors. Do you use black light to ensure testing? Training detection?
            1. Dudley: Have used black lights in the past. Members of the USFWS were doing the same. Determined by both parties to be unnecessary if crews were aware of the colors in use for that year. Separated between left and right across years, which allowed greater awareness.
2. What time of year are the fish released
    a. Archdeadon: October and November
3. How does the augmentation relate to the October sampling
    a. Archdeacon: Will wait until after sampling. In the last three years they had so many fish they did an October release but still waited until after the monitoring in the associated reach.
4. Hubert: How are the marked fish treated in the field processing and coding for the PopMon efforts.
    a. Dudley: The marked fish are recorded on the data sheets as the color and body location of each mark. These are separate field in the database. When Gary analyzes the data the marked fish are excluded from the October analysis.
5. What proportions of the fish collected in the PopMon efforts are marked?
    a. Dudley: The proportions do vary across years. From 2012-2014 with low numbers of wild fish the proportion would be upwards of 90% hatchery fish
    b. Archdeacon: Adding to Rob's comment, in 2009 we released 20,000 fish and salvaged in 2010 in that location and 5,000 were salvaged. All were wild. In 2012-2014, more of the hatchery fish were salvaged. He can provide those numbers.

3.
   a. Are the statistical analysis used in the monitoring program appropriate and in line with data distribution and characteristics?
      i. Fabrizio: Appreciate the approach that has been taken in the last few years (mixture modeling). One of the things that I think about are residual analyses and re-evaluation of assumptions. How big of a role do those questions play in the analysis?
         1. White: Residual analysis has been a mystery because of the mixture. You have the probability of a non-zero, and then you have a prediction of that particular site. For that site, you are getting an average CPUE for the site. Not the traditional kinds of regression where you can plot regressions. The sampling unit is a site. We look at the data in many different ways, but he believes we are pseudo replicating. When you start thinking about mesohabitats and other things lower than site scale, site*year interaction. I would like to hear what the panel thinks about pseudo replication below the site scale.
         2. Fabrizio: That is probably a healthy tension
         3. Hughes: The site*year is really important. Not sure that is pseudo-replication. You could argue within one year, that each site effects the other sites within the reach. They are not totally independent.
         4. Fabrizio: Pseudo-replication can be raised by lack of independence. Are you saying that the individual mesohabitats within a site are not independent?
            a. White: Analogy would be schools of people. Want to compare across grade schools. Take 20 schools. Don't use students within those schools for the tests. That is how the mesohabitats are being used (as students). Can have variation across the site, but in his opinion that is pseudo-replication
            b. Fabrizio: I interpreted as the data are nested
            c. White: The kids are nested within schools just like the mesohabitats are nested within sites.
         5. Pine: What is the treatment we are using to address this issue? If it's a high flow year it affects everything. These issues are extremely important. The key questions of the stakeholders are larger treatments on the river has a whole. I agree with Dr. White that you will have pseudo-replication at the mesohabitat scale. But I think the stakeholders are interested at the larger river scale. Going back to the by reach comparison may provide new insight.
            a. Porter: Suggests that we would learn more by looking at the geomorphic reaches rather than the diversion reaches. The habitat in a class geomorphic reach are more similar and would have more similar trends for the mesohabitats and PopMon data.
               i. Hubert: How many geomorphic reaches are there
               ii. Porter: 6-10
               iii. Hubert: how many sites occur in those reaches?
               iv. Porter: Maps available. Not sure of sites occurring within those reaches. Massong and Tasjian
               v. Hughes: Rather than 6-10 reaches could you cluster those into 2 or 3?

1. Porter: Yes (4), incised, aggrading, and stable, none of the above

6. Marcus: Going back to grade school, is it the students or the grades within the school that are analogous to the mesohabitats.
   a. White: You could look at CPUE by habitat would match that analogy
7. Marcus: By using the site as the sample unit not the seine haul or mesohabitat, one of the questions is the effect of displacement. By having multiple seine hauls in multiple mesohabitats you start to wash away the displacement issue. If they are driven from one mesohabitat into another where they are collected. At the site scale, you ignore the mesohabitat scale. The total collection at the site is where the data should be analyzed. The assumption is that displacement may play into the density at the mesohabitat scale. Only a small proportion of the habitat is sampled within a site. What kind of spatial segregation occurs at the mesohabitat scale?
   a. Dudley: Depends on the site. Since the seine hauls are 10m in length, we have 200m in total length (50 m wide) for the site. Can allow for buffer in narrow sites (5m buffer).
8. Marcus: Heard yesterday that my increasing the number of seine hauls at the sites increases the cost, but does not increase the precision of the data.
   a. White: What we found with the PopEst data the increase of area sampled within the site did not appreciably increase the precision. The only thing that increased the precision is more sites, not more sampling within a site.
   b. Pine: Read from 2011 RGSM report, page 36 provides data to support White point.

ii. Valdez: I think I have heard pretty general agreement in the use of the mixture models for these data. I don't think there is a lot of dispute on that. The question that still faces us is the very nature of those data. The 0 inflated nature of those data. Are we not measuring the variance of the sites rather than the variability in the index of the abundance at the seine haul level? The reason this is raised is that the sum of total number of fish collected in twenty hauls rather than CPUE per seine haul. The variance of the seine haul is not being carried over into the analysis. Why is this being done and what difference would that make?
   1. White: The variation across seine hauls is nested and clearly pseudo-replication. It would be like taking all of the school kids, testing the variability across school kids, and then testing across years. By summing the seine hauls and summing the area this variation is not lost and is still part of the index.
      a. Hubert: Explain why that would be pseudo-replication
      b. White: It is nesting that was discussed earlier. It is the wrong nest to test.
      c. Hughes: The mesohabitats are fake replicates of sites. Don't use them as sites. Rich is saying something total different. He is saying thinking of mesohabitats as sites, which is a totally different design.
         i. White: Rob has a graph that shows that mesohabitats are well correlated with CPUE. The study is not interested in what is higher or lower, but the total index (fish population going up or down). The models that we fit where mesohabitat has an effect over year there is a positive correlation. Are the fish population in the river changing

from year to year? Refer to Dudley presentation for data on this statement.

ii. Valdez: Back to the original question, is there a different design that would reduce the 0 inflated data? Are the CPUE data worth collecting considering the caveats and constraints?

iii. White: Even if the river that was never dry, there would still be sites with 0 silvery minnows.

iv. White: We have a clearly defined sampling framework. If the habitats are fixed, then you could modify the design to sample them. However, since the mesohabitats are not fixed you can't have a fixed framework.

v. Valdez: There is variability within sites over years. This is contributing to the variability of the index. If you stratify by mesohabitat types

vi. White: When it comes to mesohabitat types, you can't have a defined frame where those are sampled across years

vii. Valdez: The sampling frame is occurrence moving down the river

d. Valdez: What if those mesohabitats were not within a site rather than distributed throughout the river. Is there that dependence among mesohabitat types

iii. Pine: In the mixture model, could we develop other models to fit the data that are similar that have already been fit but may have specific covariant that are of interest to the stakeholders? Some examples to clarify: several of the models that are fit discharge exceedance between a period of time (June to October). Possibly incorporate a model in April or May where floodplain habitats are inundated. Another is fish stocked in October and fish captured the next year. Would expand the candidate sets of models. There is expertise in this room that could bring a new set of candidates of models.

1. White: New covariates.
2. Hubert: Do we have data to support new covariates?
   a. Porter: We can look at the number of days of inundation, acres of inundation (by year and by reach), number of fish stocked and salvaged each year.
3. Pine: The stakeholders could identify new covariates that could lead to management actions. Four to six new models with new covariates that could be fit.
4. Dudley: Relative to the existing covariates, there was some discussion regarding days with a specific flow. It was April to May. During those particular months of year there is a high likelihood of spring run-off and biological response to the water. If had a certain flow for a certain duration, based upon the knowledge that this species spawns and requires several weeks of persistence of this habitats we could expect a higher recruitment success if we could keep those nursery habitats wetted for a minimum period of time. Goes directly to acreage, but they do have some covariates of this information. It is a model based upon a model, so it has been used for insight not data analysis. Could look at additional covariates. Base concept is that spring flows and the subsequent summer drying are the important

environmental factors that would impact recruitment success. How many days before flow drops below a certain flow in June was directly requested by USFWS. The timing, magnitude, and duration analyses are in their contract. If he had free reign, they would consider other objectives but have kept the analyses within the objectives of their contract.

5. Porter: The USACE has taken a finer look at some of the hydrologic parameters (magnitude and duration) in the floodplain. Currently, their analysis points to 2000cfs as the critical threshold on the magnitude. An eleven day duration at least that magnitude or longer is the minimum threshold tied to the recruitment success.
    a. Fabrizio: More clarification. Is that just for the upper reach or for the entire river?
    b. Porter: Using the ABQ gauge, but it does appear to reflect successfully for the entire river.
6. Fabrizio: How were the number of wetted days were calculated
    a. Hydrologic inundation analysis from Flow2D and from HEC RAS.
7. Fabrizio: what is the role of remote sensing
    a. Porter: Ground truthing and surveying currently used, evaluating LiDAR
    b. Fabrizio: That limits how far back in time you can get that information. How far back?
    c. Porter: 1990

b. Are there additional analytical techniques that could be utilized that would improve the use of CPUE?

   i. Pine: There are hierarchal Bayesian antecedent models that link prior flow conditions to fish population responses. These approaches are an alternative approach that the program may be interested in evaluating. Pine will provide the reference to Atkins for review. There are different camps on these techniques, but it could be considered.

   ii. Marcus: What if we have a different way to analyze the data. Can we do something different? Instead of taking the 20 sites and looking at those as the unit. Could we instead take the same data and break them up my mesohabitat types and analyze the data that way and then collapse them. When we are dealing with fixed sites, when a site is dry the CPUE is 0. However, if you sample mesohabitats then you don’t have dry sites but find the mesohabitats where they can be found.

      1. Hubert: A mesohabitat sample frame?
      2. White: On Rob’s presentation, slide 38 shows that they are highly correlated. 2005 they all went up, and 2006 they all went down
         a. Valdez: Are they correlated because they are in the same sites. Is there an alternative sampling frame? See question 4.
      3. White: Discussion on autocorrelation. Autocorrelation is the previous year affecting the numbers of the following year.
         a. Valdez: It has been stated that the mesohabitats are not independent of each other at the site scale.

   iii. Hughes: Have the researchers looked at signal noise by visiting the same sites per year versus the variance found across sites?

      1. White: The only place that has been done is the Occupancy analysis. The encounter histories seldom show all ones. In terms of the CPUE and PopEST data, no. No, this has not been done. This would be a way to get at the delta to determine the true occupancy probability rather than detection probability and occupancy. If we could visit the same site multiple times we could develop occupancy as Delta, but not sure if we could correct Mu. Two different kinds of detection probability, species and individual. Cool to have data from multiple times. We are currently losing detection probability, which is the biggest weakness of the CPUE data. We don’t have strong evidence that it varies a lot.
      2. Hughes: Mostly concerned with the variance of revisiting a site vs the variance among sites. Not as concerned about multiple visits. If that variation is relatively small compared to that across sites, then we are getting a strong signal regarding CPUE index.
      3. Dudley: Wanted to bring attention to slide 42 from his slideshow. Sampling occasion was also considered but not listed as a covariant on the slide. The reason it was excluded is that it was not found to be correlated. November sampling with four consecutive days. Year is still the big covariant.
      4. White: The answer is still site.

5. Hughes: You could still calculate variance, if it higher than 3 then it is a useful indicator.
6. Pine: Question about slide 42. Are these the occupancy from each day?
    a. White: Each day treated as a sampling unit. Visits doesn't appear here.
    b. Pine: Is the expected value in slide 42 CPUE or corrected for non-detection
    c. White: CPUE, not corrected.

iv. Fabrizio: When I think about these types of surveys, I think about the need to detect the trend through time. Want to get a clear indication of whether this would be useful or interesting scientifically but not for management purposes. Comparing last year vs this year we saw and increase rather than the trend since 2000. Long term trend vs year to year variation

1. Valdez: Trend analysis in a formal sense, focusing on probability on an alpha level. Would provide confidence in the trend that the data are telling you
2. White: Look at slide 35. Pretty clear that orders of magnitude change with the log scale. When you are going from 100 to 1, you are looking at 5,000 times the difference. A formal trend analysis isn't needed.
3. Hughes: Looking at slide 35, those trends are very similar to Pacific salmon. Those are being driven by climate changes (water). The lows are getting lower, and that is the scary part as a fish biologist. There is a NOAA model that deals with this. I forget the authors, and can give a probability of extinction. Generally ratcheting down. Mickie's stuff is very important to make sure that the decreasing lows don't fall off of the graph.
4. White: Having a 1,000cfs threshold is difficult, should we fit a trend model from 2009 down?
5. Fabrizio: You have to know that this is a log scale and don't think about it. Does the message come through strong enough? Would it help to have additional analyses that would emphasize the changes in that graph.
6. White: I don't think you would be able to detect a downward trend because the 0s. We are looking at the hypothesis of delta (detection probability) and Mu. You could fit a trend on Delta and on Mu, but could make assumptions
7. Valdez: I have seen people fit a regression to a log type scale and appreciate Mary's question. There is a formal trend analysis (Gerrodette) that could be done, but you would have to reduce your confidence before you could see anything. Unless you take short periods of these data you won't be able to see these trends.
8. Dudley: Want to put the statistics in a biological perspective. This is an r-strategist species that literally explodes into the environment under the right conditions. Can go from 1 to over 1,000, and that is what is being demonstrated with this graphs. On the flip side the declines could be just as dramatic. Long term trends make more sense with longer lived species. With the RGSM, the trend is between year 1 and year 2, and the line is either going up or down.
9. Hubert: If you have extremely low or absent data points in your monitoring, how could you expect them to bounce back up? Are their wild fish in the river, or would any subsequent bounce be from augmentation?

a. Dudley: There are a couple of points there. When you get to a critically low level (2012 and 2014), you do get into a certain critical threshold. In past years when populations with larger populations in the fall, you could expect the end point to be higher. When discusses the 0s and the meaning of the 0s in the CPUE data, we get into the issues of the two p's (species and individual detection). This is where tools like site occupancy are very useful and provide insights into these challenges.

v. Pine: Please go to slide 34. This provides both Mu and Delta. We discussed how when the populations are really large the detection function is not going to help you. The stakeholders and managers are not worried about when the populations are large, but rather when the population is really low. Maybe some thought should be given to detection probability (individual) under low density conditions. The second point is whether the researchers have use the analyses in this plot but add in the augmented fish. Do a graph with all fish, would that provide a different picture?

1. Dudley: The site occupancy are only the same data, so Delta and Mu are not the same data.

vi. Pine: Has this model been fit with wild and hatchery released fish

1. Dudley: These data have not been fit to wild and hatchery fish. By the October survey in virtually all years the hatchery fish comprise a negligible portion of the total catch.
2. Dudley: The hatchery fish are stocked in November, survive the winter (some), and then spawn. Their progeny are then captured in October, but they are unmarked and are considered wild.
3. Pine: These creatures live three years at the very most.
    a. Archdeacon, extremely rarely 3 years, rarely 2 years. Most commonly 0-1 age class with 0 age class being the largest age class.
4. Pine: Does the Program consider the RGSM as an annual species like a scallop that only lives one year. You can't pretend that the species doesn't live to age 3 just because you don't find them. It is unusual to discount the longevity of the species from a fisheries assessment (stock assessment). This is super important. In thinking about additional analyses, the antecedent flow analyses is a really important analysis.
    a. Dudley: We do know from empirical data (ear bones) and lengths of the fish the approximate age. After examining a series of individuals, there is a report out on age and growth. That report demonstrates that there is a large proportion of 0 fish, a small portion of age 1, and a few age 2. There is not documentation of age 3. In the field, good sampling days (1990s) and could look at 10,000+ individuals we found a clear distribution that was bimodal but dominated by age 0. We could consider additional age class analyses, but in most years they wouldn't be fruitful because of low survival beyond year 1. Previous efforts were problematic. Would occasionally have no data for specific reaches.
    b. Pine: The point is that it is a fish, where more age 0. If you should have more than one age class in the data, and your age ranges are truncated then you

won't have full recovery. Should consider age classes distribution for future sampling and data analyses. When you handle so few animals, those older age classes may not be present. Everything is focused on age 0 or age 1, but if year 2 plus age classes aren't subsisting, that brings up a host of issues that should be considered from a management perspective. Why are older age classes not persisting?

   i. Hughes: That would be an important data variable if these data we being collected.

c. Pine: Size classes as age classes is problematic. Age 0, 1, and 2 lengths may overlap.

d. Archdeacon: From salvage data, all species and all sizes are being trapped in the pools. Don't see fish older/longer fish in those salvage data.

e. Pine: Assuming that the size classes are reflective of the ages, if multiple year classes are collapsed within the CPUE data, older 1990s data could have been from persistence. We are failing to fully analyze the day to consider year classes by collapsing the CPUE by length. It appears that the use of the CPUE considers these to be an annual species, and that the CPUE catch in the fall is a function of the fish that are there in that year from the previous year's spawning

   i. White: Age 0 fish are the predominant age class sampled

   ii. Hughes: In the 1990s, were the length frequency distribution similar to what is seen today?

      1. Dudley: Yes. Collected fish from the river to do an age class assessment. Did collect the largest fish that has even been collected in the Rio Grande (over 100mm). Typical is 60mm. That was an age 2+ fish meaning it survived two winters. Have a general idea of the size class distributions that would associate with those ages. There are problems with using lengths as an age and doing an analysis is problematic due to the limited number of fish. Not the situation where we are losing population due to the lack of persistence.

vii. White: Lognormal rather than alternative distributions. The benefit of lognormal is that there is no covariance. In other models (negative binomial), mean and the variance are related. Point 1. Mean and variance and uncorrelated. Point 2. Integer distributions would have to be corrected by seine haul length and 0 inflation. Lognormal provides a strong framework

4. What revisions can be made to the sampling design to improve accuracy, precision, and power to detect change in RGSM abundance?
    a. Hughes: Before you think about sampling design, you need to have clear statements of the objectives of the sampling. That is not clear in my mind. If the following list are objectives of the sampling program, then there are too many objectives. Recommend condensing the list to the one or two most important objectives. For the people at the table, what are the objectives of the sampling.
    b. Archdeacon: Program Monitoring Plan stated that tracking CPUE trends was a primary objective
    c. Pine: Detecting responses in RGSM to management actions
        i. Hughes: System wide rather than site specific responses
        ii. Pine: Maybe consider both, with depending on the scale of the management actions
            1. A desire may be to detect responses to management actions at either the river or reach scale. It may not be possible to detect at the reach scale due to the CPUE variability.
    d. Hubert: The current sampling design can detect management actions if the management action would affect the entire Middle Rio Grande reach
    e. Valdez: Don't design for numerous objectives but can possibly answer several question. That doesn't mean that the objectives of the program were intended to address those issues.
    f. Porter: Two objectives are Spring run-off flow for spawning recruitment and river continuity and river drying during the summer
        i. Hughes: Effects of salvage and the effects of augmentation
    g. Pine: We could add additional sampling sites to detect the response to a specific management action.
    h. Hughes: Increase the number of sites. Don't disregard the existing sites, but add more. Thomas said that the USFWS already samples an additional 6 sites. What about doubling the entire the sampling effort to 50 sites.
        i. White: That would reduce the standard error by the square root of 2. Does that really matter? Referred group to slide 35. Would only shrink the error bars, not change the data. Would improve the precision of the data.
    i. Valdez: Status and trend. Status is how the fish is doing now, trend is how the population is changing over time. There is no perceptible trend in data due to the extreme variability. What if you do increase the number of sites, would it facilitate a more clear answer to the trend objective?
    j. Fabrizio: You can predict what the population size is going to be the following spring assuming you have the proper habitat conditions and enough fish to spawn. This is really driven by the environment, a minimum level of spawners, so I am not sure if you need data about the population in order to predict the trajectory of the population. What would have been more useful to me is a stock/recruitment relationship? In a typical stock assessment you evaluate the size of the spawning stock and the recruitment that occurs. The relationship is often very difficult to detect, but a low population sizes it is often linear. Should there be some investigation into that relationship and how the habitat impacts that
        i. White: Plot year I plus year I+1 you will get your stock recruitment curve.
        ii. Fabrizio: the abundance sampled in October are not the fish that are spawning, the augmented fish stocking in November are likely creating the

iii. Pine: You are going to learn the most regarding stock recruitment when stock sizes are low and in the absence of stocking

iv. Archdeacon: We did stop stocking for 5 years, but the same general trends continued when there was a very low population 2008-2012 in the uppermost reach. The population still mirrored the same trends, although the numbers were lower.

v. Fabrizio: In terms of the stocking and the cessation of stocking, were there more silvery minnow in the upper reach or what was the rationale?

1. Archdeacon: Doesn’t remember the rationale
2. Porter: The hiatus in stocking the ABQ reach, it was the one reach that was perennial and wouldn’t have mortality through river drying. Let’s see if that carries through five years.

k. Valdez: The current design can address items

i. To Track the status and trends of the RGSM
ii. To assess incidental take
iii. To evaluate recovery criteria
iv. To evaluate sufficient progress
v. To determine the need for population augmentation
vi. To evaluate response to management actions
vii. To implement measures to avert population crash
viii. To track other fish species
ix. To assess demographic characteristics of RGSM, such as survival, growth, and recruitment
x.

l. Executive Committee Survey

i. 1. Provides estimates of long-term population trends (increase/decrease)
   1. Need: This is seen as a critical need by the majority of signatories
   2. Current Success: Range of responses indicates uncertainty by the EC.

ii. 2. Provides estimates of population abundance over time and area
   1. Need: Majority see this as a critical need for the Program.
   2. Current Success: Range of responses indicates uncertainty by the EC
   3. Hughes: Is it worthwhile to spend the money to estimate population abundance, if so then a different design is required.
      a. CPUE trends are sufficient

iii. 3. Evaluates species response to variations in natural conditions.
   1. This workshop interprets natural as related to hydrologic flow
   2. Need: Majority indicates needed to critical need for species response to natural variability.
   1. Current Success: Range of responses indicates uncertainty

iv. 4. Evaluates species response to management actions, such as:
   1. Need: Majority believes this is an important or critical need.
   2. Current Success: Majority believes need is addressed poor to fair.
   3. Hughes: This should be a primary goal of the CPUE program. Salvage, augmentation, flows

4. Archdeacon: Scale of the response is going to be related to the scale of the management action. Determining the scale of the management action that should be measureable in response should be clear
    a. Hughes: The Middle Rio Grande should be the area of focus, not at the site scale.

v. 5. Refines understanding of species development and behavior.
1. Need: Majority indicates needed (perhaps not through this monitoring program?)
2. Current Success: Majority indicates poor to fair or unknown.

vi. 6. Evaluates progress toward species recovery.
1. Need: Majority sees this as an important to critical need.
2. Current Success: Majority indicates poor to fair.

vii. 6. Evaluates progress toward species recovery.
1. Need: Majority sees this as an important to critical need.
2. Current Success: Majority indicates poor to fair.

viii. 7. Evaluates sufficient progress.
1. Need: Range of responses indicates uncertainty but needed.
2. Current Success: Wide range of responses indicates uncertainty and unknowns.

ix. 8. Assesses population viability and self-sustainability.
1. Need: Needed to critical need.
2. Current Success: Wide range of responses indicates uncertainty and unknowns.

x. 9. Tracks trends and abundances of other fish species.
1. Need: Needed, maybe?
2. Current Success: Range of responses indicates uncertainty and unknowns.

xi. 10. Provides high level of precision and accuracy for the cost.
1. Need: Needed to critical need.
2. Current Success: Range of responses indicates uncertainty, mostly poor to well.

m. Hubert: Which new sampling designs could address other EC objectives

i. Hughes: Each mesohabitat is seined 3-10 times? How many seine hauls per mesohabitat
1. Dudley: 5 mesohabitats, with 20 seine hauls per site divided amongst available habitat.
2. Hughes: Why not sample more mesohabitats? Sample more than 20 seines and cover more mesohabitats within the same site? Since you are sampling a small proportion of the site.
    a. White: That analysis was performed before, it didn’t have any effect. The variation is coming across from year to year.
    b. Hughes: But mesohabitat was the second most important variable
    c. White: There is variation across repeated samples, but the larger variation is across years. Within site variation is a much smaller component.
    d. Hughes: You don’t see any value in increasing the level of effort at a site, or increasing the number of sites
        i. White: The data clearly show big differences across years?
        ii. Hughes: Let me go the other way, reduce the number of sites

n. Valdez: Look at the issue in terms of representation. There are 150 miles from the uppermost to the lowermost sampling site. Each of the sampling sites is 200m long, altogether there is 4000m sampled, or less than 3 miles over 150 miles. How well do these sites represent the population for the whole area? What effect would have from increasing site numbers? The means are going to stay the same, but I am not sure if we know that.

i. White: Referred the group to slide 21. Compares population estimation and population monitoring efforts, which show similar trends. Two different samples of 20, and they show the same patterns.

ii. Archdeacon: We intentionally selected 20 new sites and used the mixture modeling to found similar results. Referred to a published paper that was distributed to experts.

iii. Valdez: Are we saying that this species is uniformly distributed across the system?

1. Archdeacon: In high population years, yes. You find it at all sites in good years.

iv. Dudley: When we think about slide 21, it was done specifically from the work group. If you follow these totally different methodologies, would you have a different answer? If we take the PopEst is being the best to the total population, CPUE is an index of abundance and have empirical data to back up that statement. These other statements are what ifs, which are important to raise. When we look at the relationships between density and CPUE we have a CPUE 1. That results in a PopEst of 100,000. We have a dataset on augmentation, where we know exactly how many fish are in the system. If we look at those two datasets, the CPUE data for the augmented data the CPUE should be 2. The last three years the CPUE for 2 for December data. From the empirical data we have, there is a reasonable agreement that the CPUE estimates are indicative of the population. The CPUE data are also capturing the abundance of augmented fish.

1. Fabrizio: More clarification of the years included in the study. Did it include high flow and low flow years
   a. Dudley: Two higher and two lower flow years. Did not include exceptionally low flow years.
2. Pine: The description above is related to predicting the CPUE based upon known populations of the stocked fish over the last three years (2012-14). The question is what were the spring flows like 2012-2014
   a. Dudley: Referred to slide 37 for the hydrograph
   b. Pine: Doesn't look like there is a strong contrast in the flows for those years. Were those average, low, or high flow years
      i. Porter: Below average spring flows. You can look at slide 37 and see that none of those years exceed 1,000 cfs
      ii. Dudley: These are taking as monthly averages, so individual flows could have exceeded the 2,000cfs threshold. The point of bringing this up is that I wouldn't go too far with 3 years' worth of data, but they were low flow years during the fall and most importantly where no wild fish were found. The monitoring data reflected something in the river. No fish and then picked up a predicted signal associated with augmentation. The current monitoring program may have value in assessing augmentation.
      iii. Dudley: In reference to the EC Summary. Do we have confidence that the CPUE index is reflective of truth in true abundance? The empirical data that are available support this.

iv. Valdez: What is the proximity of the sample sites to where the release of the fish? Did it reflect where the fish were released or the mixing of the fish

1. Archdeacon: In the last four years, there has been purposeful avoidance of ASIR sampling sites, and USFWS has avoided releasing on top of ASIR location. We try to release in between ASIR sampling sites.

c. Dudley: Those are the entire year flows

o. Valdez: Has there been some kind of a reconnaissance of the entire river to establish if there are differences in numbers of fish by geomorphic reach

i. Hughes: Do the 20 current sites cover those geomorphic reaches?

ii. Dudley: Not sure how the geomorphic reaches are defined? Request for a document that clarifies those locations?

1. Porter: Will identify the reference and provide to Atkins

p. Valdez: Let's look at an alternative design to look at trends in abundance and the precision of abundance. Goal is to improve the precision of the CPUE index. My basic approach would not involve fixed locations.

i. Pine: Drawing 1 is existing schematic

ii. Pine: Drawing 2 is proposed schematic that address Valdez comment

1. Encounter sampling. Map the river, then avoid nonproductive mesohabitats and focus on the productive mesohabitats

iii. Pine: Consider low flow/low abundance sampling. Does the existing design tracking those?

q. Archdeacon: If you do 400 seine hauls and you establish that the fish is rare, then why do you need to do more sampling

i. Valdez: For precisely that reason. If you are showing an insensitive level of detection, don't we need to increase the sensitivity of detection? Is it important to know that there are fish in the system, but in a different location?

r. Valdez:

i. Alternative design

1. More diverse investigation

ii. Supplemental design

1. With many zeros, trigger supplemental sampling

s. Fabrizio:

i. Are you saying as density goes down, that they are not being encountered? If the situation regarding RGSM would lend itself to multi-state occupancy models? With those, you can define a state as different levels of abundance, with each level have different values for occupancy and abundance

1. White: We all agree that the detection probability decreases with occupancy. If you do 400 seine hauls and still don't detect species, is that small improvement beneficial to the program?

t. Porter: Yesterday we discussed catchability. Maybe an addition to the sampling design but a very rigorous of gear types, flow, and depth to perform a good catchability study. Do depletions with the different gear types of flow and water depths. Seining, electrofishing, single net, dual net, etc.

u. Marcus: If I were a water manager or an irrigator, and I looked at the CPUE data that varies by orders of magnitude over time back in history and currently. Back in history the low years were followed by big surges in fish. If that fish can come back from zero, why should I be concerned about zero? Not giving me information on the potential of the species to recover. There are fish that are still reproducing from the zero CPUE. I need a better way to understand the population information that is improved from CPUE.

  - i. Hubert: A trigger to add supplemental sampling on top of the PopMon sampling efforts.
  - ii. Archdeacon: Big picture, historically the species has already lost 90% of its range. The goal of recovery is not to hover on the edge of extinction but rather have the change to avoid being zero in low flow years.
  - iii. Pine: If 400 isn't enough, do you want to go out and do 800 is not realistic thinking. If we are thinking of triggers, could you consider repeatedly sampling in a subset of sites to understand capture probability at those low flow conditions? This would help understand detection at the low flow. Could trigger a different spatial or different intensity of sampling.
    1. White: Is that displacement behavior? When it gets this low, we haven't seen it come back from zero to a very large magnitude.
    2. Marcus: We don't want to keep them on the edge of extinction, but when you see the variability in the CPUE
    3. Archdeacon: You want to prevent yourself from going extinct, you either need to be very abundant or geographically diverse. For this species, both are no longer options for the RGSM.

v. Pine: Under the average or lower catch conditions (over the last 5 years), are you equally likely to find the RGSM in the available mesohabitats types or is there difference of capture in the habitats.

  - i. Dudley: Provided a summary of sampling quotas for the different mesohabitats types
  - ii. Pine: Supplemental sampling should focus on backwaters and pools, not the low catchability mesohabitats, but only if research confirms that those habitats are where the fish would congregate in those habitats and following the habitat utilization identified during higher flow sampling.
  - iii. Dudley: We are talking about targeted sampling. If things are really low would it be worthwhile to find those areas where we would expect to find higher densities. The questions are better addressed by looking at the broader issue of whether we are detecting the species at the site. The site occupancy study provided insight into this question, and allowed us to determine presence/absence
    1. Pine: The site occupancy work determined that there was high site occupancy and high flow. Please confirm that the occupancy work also takes place low flow areas
    2. Dudley: The occupancy work is ongoing. There is an appendix that makes the dataset current through 2014. The site occupancy during successive years have declined year over year to site extinction. Site extinction probabilities
    3. Pine: Those are site extinction probabilities, which is a different index than true species extinction. Can you get inferences from the data that would inform management actions? In years with low CPUE, is there different utilization rates of the available mesohabitats. If differential habitat use is occurring at low fish abundances, then that might inform management actions related to promoting species resilience through conserving or restoring specific habitat types.

            4. Hughes: I believe Gary showed me graphs that addressed through this issue over time. There is not a consistent signal over time. The fish is sometimes present during high flow and low flow times.
                a. White: These were CPUE data from the November data where we had repeated counts. When you look at each site repeatedly over years, they bounce all over the place.

w. Hubert: What studies or research are available that the experts may not be aware of? Biology of the fish, datasets, etc. that could be evaluated?
    i. Archdeacon: The salvage dataset could be made available, which has not yet been peer reviewed.
        1. Fabrizio: what is the question? Status and trends of the salvage data
        2. Archdeacon: Findings follow what ASIR what would predicted. Lots of YOY or almost none. Not a distinct decline.
    ii. Valdez: Data are taken from a variety of sites other than the 20 sites. My observation would be that it is worthwhile to perform an analysis of alternative designs. Several years of data. Data collected by the USFWS by Remshardt. Some of those sites had numerous seine hauls, but the length of river was missing. Can’t convert to CPUE because missing length data.
    iii. Archdeacon: Tribal data, but there are sensitivities with those data
    iv. Hughes: Mike Marcus has a report that may have been pertinent. It was in the set of additional zip files. He handed me files 12b and 4b from a file of 15. 12b is SWCA 2015. Main Channel Fisheries Monitoring Draft Report. 4b is Dudley et al. 2011 Rio Grande Silvery Minnow Population Estimation
    v. Archdeacon: All marked fish, where they were released, and when. Plus the recapture database

x. Valdez: With regards to what does the 0 CPUE mean as an observation. To managers it means nothing. There is not a good understanding of CPUE and what it means. What would be useful if the CPUE data could be translated to a prediction of extinction or population viability? Let’s be cognizant that 0s do mean something and are important, and want to make sure that we understand what these data mean. Need a connection between the biologists and the managers.

y. Hughes: Not sure if the listed species have instream ecological minimum flows. NO

Appendix G
Recorded Notes during the Workshop
(Day 3)

1. **Is the CPUE index appropriate for monitoring the RGSM in the Middle Rio Grande?**
    a. Panelists Response: YES
        i. Rationale
            - Seines are applied globally for fisheries monitoring and assessment
            - Protocol for operation of seines has been standardized (crew leader etc)
            - Seining is an effective method for sampling small fish (particularly age-0)
            - Seining protocol has been in place for the entire program (since 1993)
                a. Appropriate corrections to the data recording protocol have been implemented since 2002
            - The standard methodology reduces potential for crew variance
            - CPUE is widely used index of abundance or density in freshwater fisheries management, and the potential sources of variation are widely documented
            - Research on the Rio Grande provides empirical evidence of a convincing correspondence between CPUE and estimates of abundance derived from an independent study implementing a different methodology (gear)
            - Research has shown that environmental factors affect both CPUE and catchability.
                a. The CPUE index can be standardized in the presence of environmental variability using analytical methods.
            - We conclude that CPUE provides a useful signal that reflects the relative abundance of age-0 Rio Grande Silvery Minnow in the Middle Rio Grande.

2. **Are the monitoring plan and sampling design appropriate for tracking the status and trend of the RGSM in the Middle Rio Grande?**
    a. Panelists Response: YES
        i. Rationale
            - Fixed site designs often provide CPUE data with less variance than randomly chosen sites.
            - Fixed site designs provide earlier trend detection.
            - An independent study using a GRTS (Generalized Randomized Tessellated Stratified) design yielded similar results in the Middle Rio Grande.
            - The Program has demonstrated the ability to sample fixed sites on a monthly and yearly basis.
            - There is a reasonable spatial distribution of fixed sites over the Middle Rio Grande and within the three reaches.
            - The three reaches are congruent with the manner in which the river has been segmented for water management purposes.
            - The 20 sites are a reasonable sample size.
            - The design incorporates sampling across available mesohabitats.
            - The design allows for effective sampling over a wide range of discharges encountered seasonally.
            - The design accommodates variation in mesohabitats occurrence both spatially and temporally.
            - October is the most appropriate index period for the annual assessments.
            - We conclude that the design allows for tracking abundance and occurrence of age-0 RGSM.
        ii. Observations
            - Consider implementing a sampling design that facilitates occupancy modeling in addition to the existing PopMon sampling in October.

3. A. Are the statistical analysis used in the monitoring program appropriate and in line with data distribution and characteristics?

a. Panelists Response: YES

i. Rationale

- The use of mixture models is appropriate for estimating the CPUE index utilizing both zero and non-zero catches.
- Mixture models consider mesohabitat and year variability and improves CPUE estimates.
- Mixture models allow evaluation of covariate influences on CPUE estimates.
- We conclude that mixture models represent a positive step forward that is more informative than previous approaches.

ii. Observations

- Continue using the 5 mesohabitat classifications.
- Consider key drivers of mesohabitats variability such as water velocity as well as replacement of the mesohabitat factor in the mixture model with velocity.

3 B. Are there additional analytical techniques that could be utilized that would improve the use of CPUE?

a. Panelists Response: UNRESOLVED
    iii. Rationale
        - Because each seine haul has a different length, the CPUE estimates should not be treated as integers.
            a. The two parameters (mean and variance) of the lognormal distribution are independent.
            b. The panelists support the use of the lognormal approach.
        - We recognize that there are other techniques for dealing with zero inflated data.
        - An alternative to the parametric mixture model may be Bayesian hierarchical models.
        - CART, boosted regression trees, random forests, and similar techniques may be used to examine relationships between hydrologic covariates and CPUE to determine thresholds.
        - The assumptions of the mixture models need to be fully defined and explored

4. **What revisions can be made to the sampling design to improve accuracy, precision, and power to detect change in RGSM abundance?**
   a. Panelists Response:
      - A revision should not be implemented without strong empirical evidence that an alternative sampling method provides more precise estimates of CPUE and offers constant catchability.
      - Raw data from large mesh nets and larval nets should never be combined into a single index because of the different sampling efficiencies of the two gears.
      - Possible additions may further strengthen the program:
         - Further studies on factors affecting catchability could lead to changes in the covariates measured during sampling (or independently) and the analytical method used for estimating CPUE.
         - Precision can be improved by addition of sampling sites.
         - Stock/recruitment studies to evaluate the abundance of spring spawners relative to fall recruitment.
         - Genetic fingerprinting studies of wild and hatchery fish to determine hatchery contributions to the spring spawners.
         - Efforts to standardize sampling and analytical methods across agencies with RGSM interests.
         - Age specific fecundity and survival rates based upon pre-breeding census methodology (fall).
      - There is potential for further data use from the PopMon program in management decisions
         - The analyses in Dudley *et al*. 2015 could be used to assess discharge effects on occurrence and abundance.
         - Apply the existing PopMon data to the recovery goals outlined in the RGSM Recovery Plan.

EXPERT PANELIST OBSERVATIONS

1. River flow regime and abundance of the RGSM are strongly associated.
2. There is an apparent lack of attention to long-term climate change issues and integration with climate change planning efforts.
3. There is an absence of minimum instream flow requirements to assure recovery.
4. Using hatchery fish to avoid extinction may reduce the overall population fitness.
5. There is insufficient data integration within and among agencies.
6. Rigorous adaptive management processes are needed.
7. If there is a desire to estimate relative abundance in extremely low flow years, the panelists foresee an immense challenge to develop and carry out a statistically valid sampling design.
    a. There is consensus among the panelists that such additional sampling would add clarity to the recovery issues documented by the PopMon program.
8. Additional gears may be added to the existing sampling design (fyke nets, bag seines, eDNA, and/or acoustic camera) to improve characterization of age distribution.
9. The research done on the RGSM warrants publication in high level peer reviewed journals.

Day 03 Afternoon: RGSM Population Monitoring Workshop

1. Porter: Focused monitoring compatible with CPUE may be more compatible with adaptive management, and appreciate the comments regarding low flow and CPUE to make sure that they are addressed in the report relative to Question 01.
2. Kris Schafer (USACE): Sometimes difficult to avoid engaging in policy, and want to encourage the panel to avoid getting involved into policy related to the Program. The USACE in the process in developing an adaptive management program, and look forward to using the results from this workshop in the adaptive management process.
3. Pine (speaking on behalf of MRGCD, APA, the Authority, and ISC): Reads a statement that will be entered into the record as "Written Statement 01".
4. McKinstry: The BOR supports sound science to make river management action decisions. The BOR did not see a lot of surprises here. The panel findings are in line with what was expected given the priorities and constraints of the program. The scientific work is good, and does not need significant improvement. One of the important questions is "how well do you need to know zero", and what kind of decisions are being made of these data. From the BOR standpoint, they don't see a large investment in the results that would lead to different management decisions. The BOR requests that the panel include some prioritization in the recommendations and observations that were made in the presentation this morning. The BOR doesn't have an unlimited budget but recognizes that there are other things that could be done in order to improve the program. We are open to that. The BOR want to work with the interagency partners to evaluate large and collaborative research projects that can benefit the system.
5. Matt Schmader (City of ABQ): Wants to make some statements that are different than the others that have been made. Listened from the point of view from a social science, which includes a lot of impoverishment. As an outsider trying to look in, he is not sure whether the beginning of this effort ever came out of a structured, scientific research design. The sampling design is not research design. The sampling design is something that happens as a matter of necessity. He does not believe that there was a scientifically structured research design that has guided this process. We have proceeded with induction, which is the collection of information. The person who is the most right is the person who can compile the largest pile of facts and argue from the position of the most data. Induction is a justificational exercise. The opposite is called deduction. Hypothetico deduction involves trying to prove oneself wrong that leads to new research questions. Most of the research to date is based on justificational induction. The current research design is too inflexible to adapt to the needs of the changing system. There are piles of facts that retrodictively try to accommodate the data. (Post hoc retrodictive arguments). Deduction tells you to setup a hypothesis and try to prove yourself wrong. We have lots of 0s, and have had some interesting conversation. If this was a commercial operation looking for as many fish as possible, you would catch the most fish possible that you could. This is not being done on the Rio Grande. The research design should be hardened off the control and vary against that my choosing new sites that reflect off of research questions. I would defer to the panelists to develop the research questions, but the publication (Porter delivered) provides this type of approach. It is possible to evaluate this from where we began, where we have come, and what we desire moving forward. Want to avoid a "my expert is smarter than your expert" which has prevailed in this program, and is not the way that science should proceed.
6. Valdez (New Mexico Interstate):

a. What we are doing here today is important to the stakeholders of this program. Along those lines it is important that a reliable measure of the key resource of the program is clarified and scientifically based. I appreciate the efforts of this workshop. There have been some progressive and productive discussions. I see this as the beginning and not the end. I think that there will be some recommendations, and I look forward to those from the panel experts. I would ask that the experts provide insight into the general overall question: how well does this program characterize the short and long term trend of the species. How well does this program enable managers to know if their management actions are doing any good or not?
b. I think what we have heard today lays the foundation and identifies the need for additional evaluation and analyses of the program and program data. Consistent with earlier comments, and with the observations of the panel experts, there is encouraged continued and improved collaboration between the various stakeholders.
c. Fundamental reiteration of the first point. An encouragement of the various scientists of the program to embrace the fundamental concepts of science and apply them going forward with a productive and scientifically reliable program.

7. David Gensler (Middle Rio Grande Conservancy District): Reads a statement that will be entered into the record as “Written Statement 02.”
8. Janet Jarratt (Assessment Pairs Association): She is a farmer in the valley, and what she likes to think of herself as a real stakeholder, because her livelihood depends on the management decisions. She is on the Executive Committee and only non-compensated person. She is here before it matters to her and she has skin in the game. A lot of perception of conflict of farmer vs fish is false. No one wants to the extinction of the fish. Many of the people that she represents have been on the land for many hundreds of years, and they are from an economically depressed constituency. Every dollar and every cubic foot matters. That means that how CPUE is used matters a lot. One of the ways that it matters is that if CPUE is used as part of the annual progress metric, the CPUE is a hindsight. How does that help you plan for next year? She was chairman of the MRGCD before, and understands this from a water manager perspective. If CPUE is used for annual progress and is a hindsight view, the 0 catch data don’t support the management decisions (water managers and farmers), which have to be made 3-5 years in the future. The water managers need some amount of certainty and confidence in the results. Is CPUE the best metric to be used for sufficient annual progress that make water management decisions that affect farmers directly? One of the other expert panel observations, expansion of data collection to improve CPUE, particularly eDNA. Conclusion 3 about minimum flows. This river system is fully appropriated if not over appropriated. All of the water is owned. While the fish are being kept alive, the water that is doing it is coming at the expense of the constituents that own the water and are not being compensated ($15,000-$20,000 per acre/foot). Who is going to be paid for the use of the water associated with the minimum flows? We have to be more creative in habitat restoration, creation, and I look forward to being involved in adaptive management. I appreciate the opportunity to put a face by the non-scientific people who are impacted by these management decisions.

9. Billings (Water Utility Authority): In the words of Mark Twain, the Rio Grande is the only river that needs to be irrigated. New Mexico is losing people due to economic activities are also drying up. Water is an important part to reverse that trend, and is critical to our future. Each and every drop is important. CPUE needs to evaluate the effectiveness of water management decisions. We have to prove to ourselves that we are making good environmental and economic decisions.
10. Wally Murphy (USFWS): In the USFWS, we have a mantra that is codified in statute and regulation. The use of the best available scientific information in our decision making process. We have worked closely with ASIR, and have come to have a high amount of respect for them and the work that they do. We have learned about the statistics from Dr. White, so this is all a validation of what we have come to know and expect from ASIR. We look forward to being able to use this information moving forward. We are very deep in the Section 7 process for the Middle Rio Grande. We have some hypothesis and solutions, including the Hydrologic Objective, which is a reflective of the relationship between flows and the reproductive success of the fish. We hold that hypothesis from what we know from the CPUE data. We are looking at ways to improve the use of that information.
11. Mike Hamman (Middle Rio Grande Conservancy District): I come from the position of a senior decision maker. In my position I represent 12,500 constituents that include MRG Pueblos that are also underrepresented here today. There are another 250,000 people that are impacted by activities in this District. From an ESA perspective, it is important that we can continue to function while searching for a recovery.
    a. Overall hope to get to a point where the rancor and dispute of the scientific status of how CPUE is used and how it is applied in the future for the species as we start a new recovery program. It is important for the panel to understand that we come to consensus on the status of the species and identify what must be clarified to make the program stronger and reach a consensus to recognize each other interests as equal so that we can be truly collaborative and design an adaptive management program that will allow us to measure the impact of adaptive management decisions. What do we need to do to bring together a very carefully managed program that allows for success. We cannot repeat the last ten years. What I hope for is a starting point with the experts that is a launching point. We have never established our science advisory council that would allow us to develop a rigorous program that efficiently uses our resources and has clearly defined actions and responses. There is more than data that is not being integrated, and I really want to build on this collaboration today and close the door to apply what we have learned to a really valuable adaptive management plan. There is a few areas that we need to hone in and design other data collection programs in the low flow realm to understand how to reset the river with longer term conditions that will allow this species to flourish and avoid extirpation. There are new basin studies coming forward. The instream flow cannot be sustained because we don’t have the water. We can strive instead to minimize drying and maximize the habitat available for this species. Maximize opportunities when the water is available and then maximize the refugia where we can get the age 1 and age 2 to spawn and secure the future. Hopefully you can use the thoughts and comments to shape your thoughts for the program moving forward. We also would like feedback on how to develop the science advisory panel

b. Would like clarity on observation 7a, is that in relation the recovery plan?
c. There are a lot of people relying on sound scientific design that are juggling limited water and fiscal resources.

12. Grace Haggerty (Interstate Stream Commission): Not sure if this workshop worked for all of the needs, but believes this was the best beginning since she has come into her position. There were a lot of points and side conversations that came up that she wasn't able to be a part of. She wants to ensure that moving forward that they really look at all of available data. Also responsible for Otowi Index upstream of Cochiti Reservoir, and wants to make sure that the Middle Rio Grande and also deliver to southern New Mexico and Texas. There is a lot of information that didn't go in front of this panel and narrow the questions. The ISC also wants to echo that there is a lot of money going into water management and geomorphology issues, and this money needs to be justified. Whether through refinement of creation of new strategies she needs to be able to provide results that can evaluate the management actions for their success or lack of success. She is aware that these issues on water supplies, use, and money are common to other programs that are reviewed nationally by this panel. The ISC provides up to $2M to this program.
13. Brent Rhees (Federal Co-Chair for the Rio Grande Collaborative Program): Thank you to those around the table. Workshop took a lot of planning over several years. In the room we have several EC members and collaborative program members. What Matt of ABQ said is that the "table is set" for moving forward. We all have ties to the river, even though our relationships are unique. As we have these additional question in front of us, the answers should motivate us to move forward.
14. Marcus (APA): My perspective on the RGSM topics is habitat restoration. I want to reiterate some points and emphasize some things from the expert conclusions
    a. Day 01 talked about CPUE being a valuable index. My conclusion was that maybe, it depends. It was pointed out in the conclusions today it is good for age 0 fish. Not clear if it is good for other ages. All of the fish sampled in November are the age 1 fish that are the result of the hatchery fish that were stocked. In November, we are only measuring the age 0 fish that were spawned the preceding spring during high flows
    b. Day 01 RGSM are a schooling fish. Question whether the sampling method are adequate for schooling fish. There was a fair amount of discussion that the sampling is adequate, but some of my sidebar conversation continue to provide uncertainty
    c. Day 02 focused on alternative sampling methods and designs. Repeatedly heard that the current methods and design are adequate for age 0 fish and not older fish. Also learned that adding sites would increase precision but not by much. If we increase sampling within a site, it would increase precision which would be a more precise 0.
    d. I get the feeling that the from the discussions that all of the RGSM collected in October are from the hatchery release the preceding year, so you could almost consider the RGSM a put and sample fishery. This probably has management and decision implications.

15. Valdez: Similar thoughts to Marcus. I would make one request of the expert panel to help us reconcile the issue of the 0 catches. This has been brought up a number of times, and we have wrestled with this a number of times. What does that tell us about overall abundance? Your insights would be valuable when we are dealing with an endangered species when apparent abundances are as low as they are. Monitoring and management perspective is requested.
16. David Gensler (MRGCD): Since Rich brought up the 0 numbers again, he is holding up a graph(Written Record 03) of the last 100 years of flows. The discussion regarding of the CPUE relation to the hydrology (fish to flow), if you use these assumptions like they have been presented today, it looks like there are 20 occasions over the last 100 years where you would get a CPUE of 0. Of all of these apparent 0s that appear to occur, these fish still must have been finding a way to survive.
    a. Marcus: My perspective is from restoration. How did this fish get to be what it is since it became a species. One of things we have learned is how resistant some of the younger age groups is how resilient it is to poor water quality and low DO and high temperature. Half of them can survive in almost 0 mg/L DO when compared to 4 or 6 like most species. They can also survive in 100 degree F water. From an evolutionary perception, that kind of resistance from an evolutionary basis can only occur from remnant pools with hot water and low Dos. River themselves don't have these kinds of temperature and DO fluctuations. Suggests evolution in isolated ponds or pools in the river. Refugia are something important that still don't occur. Hydrated floodplain that allowed them to survive. Similar strategy to Topeka shiner, when they kept the stream wet the Topeka shiner would lose dominance as the predators and competitors were able to also survive. The presence of refugia is very important.
17. Joel Lusk (USFWS): We don't have a lot of empirical data on the history and evolution on the species. There is an unpublished USGS study that provides information on Marcus' points.
18. Pine: Not only is there interesting information related to the CPUE indices. The occupancy work is very important from the program perspective regarding the persistence of the species. Rob Dudley has made these available. Figures from 2014 draft report Figure B2 (Site Occupancy Model), across all ages seem to decline in site occupancy, B3, B4, and B5 are individual age groups. The age 1 and age 2 fish site occupancy declines are not as strong in recent years as age 0 has experienced. Might be good for Figure 11 to be expanded upon. We look at this plot a lot. Might be useful to think about showing two generations of the fish on a normal scale combining site occupancy and abundance context. Would show densities by habitat type in low flow years.
19. Grace Haggerty: In the discussion on the 20 fixed sites, what appears to me is that you have to look at the 20 sites as one result for the river. You could not look at the individual sites within a reach or a segment or a reach. Is that correct? If that is the case, that gives me a little concern because we are looking at doing flow management, habitat restoration within different parts of the river. Geomorphologically, the river changes quite a bit through the 150 mile stretch. How do we determine if large scale projects are making a difference using CPUE data, or is another monitoring program needed to address those questions?
20. Jennifer Faler (EC member from BOR): I see this as a launching pad for the future. Folks that want to know more about that 0 is getting us into the adaptive management world, not just the population monitoring effort. Need to think about how we are going to use this into the future from the perspective of changing management actions.

21. Valdez: Request for Atkins to advise on the timing of the document from the expert panelists.
22. Hughes: Request for clarification on report review schedule.