Population Monitoring Work Group Meeting

April 28, 2020

Meeting Materials:

Agenda

Minutes

Draft 2 Consolidated Recommendations of Two Expert Science Panels on Monitoring of the RGSM [read-ahead, draft]

Draft Executive Summary: Age-Specific Survival of RGSM [read-ahead, draft]

Draft Executive Summary: Consolidation of Mesohabitats for Monitoring RGSM [read-ahead, draft]

Revised MRGESCP PMWG 2020 Work Plan [read-ahead]

Middle Rio Grande Endangered Species Collaborative Program

Est. 2000

Population Monitoring Work Group (PMWG)
April 28, 2020
1:00 PM – 4:00 PM

Zoom Information:
https://west-inc.zoom.us/j/8983593120
Call-In: +1-669-900-6833; Meeting ID: 898-359-3120

Meeting Agenda

1:00 – 1:15	**Welcome, Introductions, Agenda Review, Meeting Notes** ➢ **Decision:** Approval of April 28, 2020 agenda ➢ **Decision:** Approval of March 25, 2020 minutes Read aheads: ☐ April 28, 2020 meeting agenda ☐ March 25, 2020 meeting minutes	*PMWG Co-chairs*
1:15 – 1:45	**2020 Work Plan** Read aheads: ☐ Revised PMWG 2020 Work Plan	*Rich Valdez*
1:45 – 2:15	**Review Executive Summaries** Read aheads: ☐ Consolidated Recommendations Report ☐ Age-Specific Survival of Rio Grande Silvery Minnow ☐ Consolidation of Mesohabitats for Monitoring RGSM	*Kevin McDonnell* *Catherine Murphy* *Rich Valdez*
2:15 – 2:25	**Break**	
2:25– 2:40	**Summary of Technical Modelers Webinar**	*Kevin McDonnell*
2:40 – 3:45	**Discuss Scenarios for Integrated Model** • Follow-up Questions on Model Framework • Develop Model Scenarios Read aheads: ☐ Example Scenarios	*Rich Valdez* *Charles Yackulic* *Joel Lusk*
3:45 – 4:00	**Wrap-Up** • Announcements • Action Items • Next Meeting	*Rich Valdez*
4:00	**Adjourn**	

Middle Rio Grande Endangered Species Collaborative Program

Est. 2000

Population Monitoring Work Group (PMWG)
April 28, 2020
1:00 PM – 4:00 PM

Location: Zoom meeting

Meeting Minutes

Decisions:

- ✓ Approval of April 28, 2020 PMWG meeting agenda.
- ✓ Approval of March 25, 2020 PMWG meeting minutes with the following revision:
  - o In the action items list, replace "Utah State University" with "Colorado State University".
- ✓ Approval of revised 2020 PMWG work plan, with possible amendments of Element 2 dates based on Charles Yackulic's input.

Action Items:

WHO	WHAT	BY WHEN
Rich Valdez & PST	Discuss potential dates for the next PMWG meeting with Charles Yackulic and send out a doodle poll	May 4, 2020
Rich Valdez	Discuss deadlines for Element 2 of the 2020 Work Plan with Charles Yackulic and revise as needed	May 6, 2020
Catherine Murphy	Distribute to the PMWG full comments on the executive summaries as a writing guide	May 8, 2020
Rich Valdez	Write up the population structure questions from the discussion to use as modeling scenarios	May 8, 2020
Mike Marcus	Write up the habitat/flow trade-off questions from the discussion to use as modeling scenarios	May 8, 2020
PMWG members	Send Rich Valdez and Debbie Lee any further ideas for modeling scenarios	May 8, 2020
Joel Lusk	Send the scenarios presented to the technical modeling group to the PMWG	May 8, 2020

PST	Discuss inclusion of a PMWG progress report on the next Executive Committee (EC) agenda with the EC co-chairs	May 15, 2020
PMWG members	Review and provide comments on the Consolidation Document and the two example executive summaries	May 15, 2020
Catherine Murphy & Kevin McDonnell	Take the "Age-specific survival of Rio Grande Silvery Minnow" executive summary through the review process	May 15, 2020
Catherine Murphy & Kevin McDonnell & Mike Marcus	Revise the "Consolidation of Mesohabitats for Monitoring RGSM" executive summary	May 15, 2020

➢ **Next meeting**: TBD

Welcome, Introductions, Agenda Review, and Meeting Notes

Rich Valdez, SWCA and the PMWG chair, opened the meeting and led introductions. He reviewed the meeting agenda. He then reviewed action items from the March 25, 2020 meeting, and asked for comments on the meeting minutes. The following updates were given:

- Charles Yackulic, U.S. Geological Survey; Joel Lusk, U.S. Bureau of Reclamation (Reclamation); and Shay Howlin, Program Support Team (PST), discussed the 1996 FLO data, and agreed that that data should be entered into electronic format. Once the transect data is entered, it will be posted on the Program Portal.
- The Zotero library has been formed. If anyone needs help uploading files or editing metadata, email Debbie Lee, PST, for assistance.

Rich shared with the group that Joel L. has stepped down as PMWG co-chair due to his workload, and expressed his appreciation for Joel's work as co-chair. Joel will still be participating in the PMWG and, along with Eric Gonzales, representing Reclamation.

✓ **Decision**: Approval of April 28, 2020 PMWG meeting agenda
✓ **Decision**: Approval of March 25, 2020 PMWG meeting minutes with the following revision:
  - In the action items list, replace "Utah State University" with "Colorado State University".

2020 Work Plan

Rich V. reminded the group that at the last meeting, participants discussed the 2020 PMWG Work Plan and requested revisions. He presented the revisions to the PMWG. The group agreed to the following further revisions to the 2020 PMWG Work Plan:

- Include footnotes to reference the relevant science panel reports and the integrated stock assessment model
- Add a new subtask under Task 1: Work with the PST to integrate recommendations into the adaptive management process
- Include new subtask under Task 2:
  - Develop model parameters

  - Conduct sensitivity analyses
- Rename “tasks” to “elements”

During the discussion, Rich V. made the point that the integration and coordination with the model being developed by Utah State University (USU) to reanalyze the hydrobiological objective is outside the scope of the PMWG. He noted that the work group’s purpose was to assist Charles Yackulic in the development of the integrated stock assessment model, and while the group will take into account other models, it will not enter into a formal evaluation or comparison between that model and any others. Kevin McDonnell and Catherine Murphy, PST, added that in the future, the goal is to build a decision tool that incorporates learnings from all the models.

- ➢ **Action Item**: Rich V. will discuss deadlines for Element 2 of the 2020 Work Plan with Charles Yackulic and revise as needed
- ✓ **Decision**: Approval of revised 2020 PMWG work plan, with possible amendments of Element 2 dates based on Charles Yackulic’s input.

Review Executive Summaries
Rich V. reviewed the revised consolidation document. He noted that there were no volunteers to take on contributing authorship or reviewer for any of the 22 topic areas, and encouraged group members to volunteer once they have seen examples presented. He then noted that there were two example executive summaries prepared: he had prepared one on age-specific survival of Rio Grande silvery minnow (RGSM) and Mike Marcus had prepared one on consolidation of Mesohabitats for monitoring RGSM using the template discussed at the last meeting.

Catherine M. then thanked Rich V. and Mike M. for providing the examples as a way to spur discussion. She shared her initial reactions to the example executive summaries:
- Moving the Management Implications section to the top of the document will highlight that for readers. If this is proves redundant with the Program Goal section, those two sections can be combined.
- The Program Goal Relevance section is meant to be a short pitch for why this topic is important to the Program.
- The Literature Summary should summarize the findings of each citation, focusing on conclusions. There does not need to be a lot of data cited and long quotations. Instead, summarize what the reader should be learning.

Kevin M. added that these executive summaries should be fairly quick to develop and short in length. He reminded the group that the PST was available to help the writers, and there was a review built into the executive summary development process, and it is laid out in the template. Rich V. noted that it was important that the summaries provide information that can be consumed and digested quickly by people with a range of technical backgrounds and expertise.

Mike M. informed the group that the draft “Consolidation of Mesohabitats for Monitoring RGSM” executive summary has significant overlap with another topic, spatial extent and historical availability of habitat and hydraulic quality used by RGSM, and could see a need to separate the two topics out. Catherine M. and Kevin M. offered to help Mike M. revise the mesohabitat executive summary, while preserving the information that should be included in the spatial extent and historical availability of habitat and hydraulic quality executive summary.

- ➢ **Action Item**: Review and provide comments on the Consolidation Document and the two example executive summaries

- **Action Item**: Catherine M. will distribute to the PMWG her full comments on the executive summaries as a writing guide
- **Action Item**: Catherin M. and Kevin M. will take the "Age-specific survival of Rio Grande Silvery Minnow" executive summary through the review process
- **Action Item**: Catherine M., Kevin M., and Mike M. will revise the "Consolidation of Mesohabitats for Monitoring RGSM" executive summary

Summary of Technical Modelers Workshop
Rich V. invited Kevin M. to provide a brief summary of the technical modelers workshops. Kevin M. informed the group that Charles Y., the modelers from USU, Tim Walsworth and Phaedra Budy, Rich. V., Joel L., Eric G., and himself met to discuss the two models being developed, where they overlapped, and how the two efforts can inform each other. The next step for both modeling efforts is the identification of management actions. Rich V. also began to describe a conceptual framework for designing a hydrograph and its application to identifying future management actions.

- **Action Item**: Joel L. will share the scenarios he had presented to the technical modeling group with the PMWG

Discuss Scenarios for Integrated Model
The PMWG discussed how to develop scenarios to run through the integrated model under development by Charles Y. The group developed ideas that fell into two broader categories: population structure, and the trade-off between habitat and flow, listed below:

Population Structure
1. Effect of RGSM augmentation on population (2.5 million from 2001 to 2019)
2. Effect of RGSM salvage on population
3. Effect of impediment/passage at three diversion dams on population

Habitat and Flow Trade-off
1. Spring runoff hydrograph to inundate floodplains as RGSM nurseries
2. Summer base flow to minimize drying
3. Balance spring and summer hydrographs (tradeoff spring runoff and river drying)
4. Acres of floodplain habitat needed to affect October CPUE

- **Action Item**: Rich V. will write up the population structure questions from the discussion to use as modeling scenarios
- **Action Item**: Mike M. will write up the habitat/flow trade-off questions from the discussion to use as modeling scenarios
- **Action Item**: PMWG members will send Rich V. and Debbie L. any further ideas for modeling scenarios

Wrap Up
The following items were suggested as agenda topics for the next meeting:
- Mike M. presenting on the information he compiled in the mesohabitat executive summary
- Thomas Archdeacon presenting on the results of the gonad somatic index results, and information about the larger RGSM reproductive study
- Continue the conversation on developing scenarios

- **Action Item**: Rich V. and the PST will confer with Charles Y. on his availability for the next PMWG meeting and distribute a doodle poll

Meeting Participants
Thomas Archdeacon, U.S. Fish and Wildlife Service
Lynette Giesen, U.S. Army Corps of Engineers
Eric Gonzales, U.S. Bureau of Reclamation
Grace Haggerty, N.M. Interstate Stream Commission
Shay Howlin, U.S. Bureau of Reclamation
Debbie Lee, Program Support Team
Joel Lusk, U.S. Bureau of Reclamation
Mike Marcus, Assessment Payers Association of the Middle Rio Grande Conservancy District
Anne Marken, Middle Rio Grande Conservancy District
Melissa Mata, U.S. Fish and Wildlife Service
Kevin McDonnell, Program Support Team
Kate Mendoza, Albuquerque-Bernalillo County Water Utility Authority
Rich Valdez, SWCA
Stephen Zipper, SWCA

Note taker: Debbie Lee

Consolidated Recommendations of Two Expert Science Panels on Monitoring of the Rio Grande Silvery Minnow

Richard A. Valdez and Mike Marcus
Population Monitoring Workgroup
Draft 2, April 16, 2020

Overview

The Population Monitoring Workgroup (PMWG) is charged by the Executive Committee (EC) of the MRGESCP with evaluating the monitoring program for the Rio Grande silvery minnow (RGSM) in the Middle Rio Grande. In July 2012, the EC approved the first of three tasks—that the PMWG convene a science panel and conduct a workshop to evaluate the monitoring program. The following is a summary of actions taken by the PMWG pursuant to Task 1 (workshop) and the transition to Task 2 (review monitoring plan and evaluate demographic parameters):

- July 13, 2012: EC approves charge for Task 1 (CPUE Workshop; PMWG 2012).
- May 2014: PMWG sends survey to EC on fish population monitoring needs (DBSA 2015).
- Dec 8-10, 2015: PMWG holds Independent Science Panel Workshop on Population Monitoring, Isleta Casino and Resort, Albuquerque, NM (Hubert et al. 2016).
- Apr 13, 2016: Final Report of Science Panel to PMWG on RGSM Population Monitoring (Hubert et al. 2016).
- July 12, 2016: PMWG forwards request to EC to initiate Task 2 (Review Population Monitoring Plan), and initiates evaluation and prioritization of Hubert recommendations.
- Mar 23, 2017: PMWG requests that Bureau of Reclamation incorporate eight Hubert recommendations into Population Monitoring Contract.
- Jun 2017: Final Report on RGSM Scientific Uncertainties for Adaptive Management (Noon et al. 2017).
- Nov 29, 2017: PMWG initiates consolidated review and prioritization of panel recommendations from Hubert (22, Table A-1) and Noon (19, Table A-2).
- Jun 15, 2018: Members of PMWG begin analyses of specific panel recommendations (e.g., Valdez 2018).
- Nov 11, 2018: Contracted biometrician initiates Integrated RGSM Population Model to assist evaluation of panel recommendations (Yackulic 2018).
- Feb 18, 2020: Consolidated review of Hubert and Noon panel recommendations completed and organized by category, according to subject matter and priority (Table A-3).
- Feb 26, 2020: PMWG agrees to write short summaries of scientific topics identified from prioritized consolidated recommendations (Table 1).

Consolidation Process

Following the December 2015 monitoring workshop, the PMWG began to review the science panel's draft report, and provided questions and comments to the panel with requests for clarification and possible expansion of the report. After receiving the final report (Hubert et al. 2016), the PMWG received EC approval in July 2016 to proceed with the Task 2 assessment of the panel recommendations. The following steps were taken to consolidate the science panel recommendations:

1. Each recommendation was copied verbatim from the science panel report and listed in Table A-1 for the Hubert panel and A-2 for the Noon panel; recommendation number and report page number were added to facilitate locating each in the respective report.
2. The prioritizations for each recommendation within each science panel report were added as the last two columns of Tables A-1 and A-2. Prioritizations include those assigned by the PMWG and by the Noon panel; the Hubert panel did not assign priorities.
3. The recommendations were consolidated into a single table (Table A-3) and categorized by priority.
4. Science topics were extracted from the consolidated recommendations and listed in Table 1.

The PMWG's Task 2 review produced a four-tiered prioritization system for recommendations ranging from 0, for recommendations considered outside the scope of the PMWG charge, to 1 through 3 for recommendations within the scope of the charge. The priority system was also applied to the recommendations of a second science panel on RGSM scientific uncertainty (Noon et al., 2017):

- Priority 1: Highest priority for recommendations viewed specifically as items that could be quickly assessed using existing data or other readily available information (i.e., low-hanging fruit).
- Priority 2: Recommendations considered of high importance but requiring relatively simple modification of the sampling program and analysis of the results for comparison with data collected without modifications: these recommendations were provided to the Bureau of Reclamation Contract Officer to modify the population monitoring program (PMP).
- Priority 3: Lowest priority for recommendations considered important, but requiring extensive modification of the PMP or possibly new field research.

Summary Writeups

A short write-up will be provided by members of the PMWG for each of the science topics identified in Table 1. Each Executive Summary will be formatted according to the template developed by the PMWG (PMWG 2020).

Table 1. List of recommended science topics from the Hubert and Noon science panels.

Science Topic	Recommendation Number[1]		Responsible Person
	Hubert	Noon	
1. Relationship of CPUE and true population size of RGSM	--	A1	
2. Age-specific survival of RGSM	--	A2, A3	
3. Size and age-specific fecundity of RGSM	22	A4, B3	
4. Relationship of demographic rates and abiotic and biotic factors	10, 24	A5	
5. Evaluate existence and strength of density dependence to limit population	21	A6	
6. Effect of augmentation on RGSM Population	--	A7	
7. Contribution of salvaged RGSM to population dynamics	--	A8	
8. Develop and deploy "vertically-integrating" Moore egg collectors	--	B1, E2	
9. Effect of environmental cues on spawning onset and activity	--	B2, D2	
10. Age composition of RGSM population	--	C, E1	
11. Selectivity of gears used to sample RGSM	--	E1	
12. Spatial extent and historical availability of habitat and hydraulic quality used by RGSM	16	D1	
13. Roles and relative contributions to fish production by age in channel and floodplain habitats	--	D3	
14. Evaluate management potential for fish production by reach	--	D4	
15. Consolidation of mesohabitats for monitoring RGSM	--	E3	
16. Compute CPUE from larval and standard seines by age	1, 2, 3	--	
17. Evaluate effect of zero catches on CPUE and sample design	4, 5, 6	--	
18. Effect of environmental factors on seine capture probability	7, 8	--	
19. Mixture model and alternatives for computing RGSM CPUE	10, 11, 14, 17	--	
20. Use classification and regression trees, boosted regression trees, or random forests to examine relationships between hydrologic variables and CPUE	18	--	
21.Effect of increased sample size on RGSM monitoring	12, 13	--	
22. Implement studies using different sampling designs	19	--	

[1]see Tables A-1 and A-2 for Recommendation Numbers

Literature Cited

Daniel B. Stephens and Associates, Inc. (DBSA) 2015. Survey of the Executive Committee on fish population monitoring needs. Summary Report, Middle Rio Grande Endangered Species Collaborative Program. Albuquerque, NM.

Hubert, W.A., M.C. Fabrizio, and R. Hughes. 2016. Summary of findings by the External Expert Panelists: Rio Grande silvery minnow population monitoring workshop Isleta Casino and Resort, 8-10 December 2015. U.S. Bureau of Reclamation, Albuquerque, NM.

Noon, B., D. Hankin, T. Dunne, and G. Grossman. 2017. Independent Science Panel Findings Report: Rio Grande silvery minnow key scientific uncertainties and study recommendations. Prepared for the U.S. Army Corps of Engineers, Albuquerque District on Behalf of the Middle Rio Grande Endangered Species Collaborative Program. Prepared by GeoSystems Analysis, Inc. Albuquerque, NM. June 2017. Contract No. W912PP-15-C-0008.

Population Monitoring Workgroup (PMWG). 2012. Approval of the 1st task for review of the collaborative program fish monitoring program for the Rio Grande silvery minnow. A Proposal for a CPUE Metrics and Methodologies Workshop, Submitted to The Executive Committee of the Middle Rio Grande Endangered Species Collaborative Program July 13, 2012, Albuquerque, NM.

Population Monitoring Workgroup (PMWG). 2020. Assimilation and synthesis of information and data related to the Rio Grande silvery minnow. By Catherine Murphy and Kevin McDonnell for PMWG, Western EcoSystems Technology, Inc (WEST), Albuquerque, NM.

Valdez, R.A. 2018. Age composition of Rio Grande silvery minnow: Application of distribution separation methods to estimate age composition. A data analysis done for and in collaboration with the Data Analysis Team of the Population Monitoring Workgroup, Albuquerque, NM.

Yackulic, C.B. 2018. Developing an integrated population model for Rio Grande silvery minnow in the Middle Rio Grande. U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, AZ.

Appendix A: Tables of Science Panel Recommendations

Table A-1. Recommendations and observations from the Hubert et al. (2016) Population Monitoring Science Panel. The Hubert Science Panel did not assign priorities to these recommendations and observations, but priorities were assigned by the Population Monitoring Work Group (PMWG) to the recommendations. Priority: 1 = high, 2 = moderate, 3 = low, 0 = no consideration by PMWG.

Number[1]	Page	Recommendation	Panel Priority	PMWG Priority
1	28	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.	--	1
2	28	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.	--	1
3	28	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.	--	1
4	28	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.	--	1
5	28	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).	--	1 and 2

Number[1]	Page	Recommendation	Panel Priority	PMWG Priority
6	29	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.	--	1 and 2
7	29	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.	--	3
8	29	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.	--	1
9	29	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.	--	0
10	29	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.	--	1
11	29	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.	--	1

Number[1]	Page	Recommendation	Panel Priority	PMWG Priority
12	29	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.	--	1
13	29	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.	--	0
14	30	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.	--	2
16	30	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.	--	2
17	30	Evaluate alternatives to the parametric mixture model, in particular, Bayesian hierarchical models, for estimating annual CPUEs.	--	2
18	30	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.	--	1.5

Number[1]	Page	Recommendation	Panel Priority	PMWG Priority
19	30	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.	--	3
21	30	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.	--	3
22	30	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.	--	3
23	30	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.	--	0
24	30	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.	--	3

[1]numbers 15 and 20 are missing in the original report by Hubert et al. (2016), apparently as an inadvertent error in numbering

Table A-2. Recommendations from the Noon et al. (2017) Adaptive Management Science Panel. The Noon Science Panel assigned priorities to these recommendations, and some priorities were assigned by the Population Monitoring Work Group (PMWG). Priority: 1 = high, 2 = moderate, 3 = low, 0 = no consideration by PMWG, Important = Recommendation is important, but not priority was assigned.

Number	Page	Recommendation	Panel Priority	PMWG Priority
A1	17	Clarify the relationship between the annual catch-per-unit-effort and true population size by estimating catchability.	1	1
A2	18	Determine the key, age-specific, life history sensitivities of the RGSM (that is, use Eigen- analysis methods to determine which vital rates [survival and/or reproduction] most affect rates of population change.	1	3
A3	18	Estimate age-specific survival rates	1	3
A4	19	Estimate age-specific fecundities of wild fish.	1	3
A5	19	Using statistical modeling, estimate the relationships between RGSM demographic rates and A.) hydrological factors (flow magnitude and duration, summer drying of the channel); and B.) abiotic environmental factors (temperature, turbidity, salinity); and C.) biotic factors (predation, completion, prey availability).	1	3
A6	20	Evaluate the existence and strength of any density-dependent factors that may be limiting population growth.	2	--
A7	20	Model the potential effects of hatchery augmentation on population dynamics and the significance of hatchery fish to achieving recovery objectives.	Important	--
A8	20	Determine if the collection and translocation of salvage fish during summery drying periods contributes significantly to population dynamics.	Important	--
B1	21	Development and deployment of "vertically-integrating" Moore egg collectors	1	--
B2	21	Improved assessments of relations between possible environmental cues that trigger spawning activity.	1	--
B3	21	Establish size-specific fecundities of natural-spawning RGSM.	2	--
C	22	Clarify the detail of annular mark formation on otoliths and firmly establish the longevity of RGSM	2	--

Number	Page	Recommendation	Panel Priority	PMWG Priority
D1	22	Estimate the spatial extent and hydraulic quality used by RGSM for key life-stages (spawning, larval rearing, juvenile and adult survival). Estimate how these habitats are distributed in the river channel and floodplain in each MRG reach under a range of discharges and seasonal flow regimes.	Important	--
D2	23	Establish the proximate trigger(s) for spawning by evaluating the effects of flow velocity, temperature, rate of increase in flow velocity, or some combination of these factors.	Important	--
D3	23	Determine the roles and relative contributions to fish production (age 0 recruitment and survival of all age-classes) of channel and floodplain habitat in a reach of channel and floodplain typical of the MRG.	Important	--
D4	24	What is the management potential for fish production (recruitment and survival of age 0 fish) in each reach of the MRG if the annual peak flow, and thus the nature and range of available habitats, is permanently limited below historic levels of availability?	Important	--
E1	24	Establish the age composition of the RGSM population, including A.) application of distribution separation methods to estimate age composition, and B.) gear selection study.	1	--
E2	25	Determine how the vertical and horizontal distribution of RGSM eggs in the MRG mainstream channel varies as a function of flow and location?	1	--
E3	25	Calculate revised CPUE values as mesohabitat-specific levels and do not combine across mesohabitat types. The meso-habitat specific CPUE calculated for the most abundant high density mesohabitat type should be used for assessment of trend in abundance of the RGSM population at the October sampling date.	2	2

Table A-3. Consolidated and categorized recommendations from the Hubert et al. (2016) and Noon et al. (2017) Science Panels.

Number	Priority SP/PMWG	Hubert	Noon	Consolidated Recommendation	Progress (see Literature Cited)	Status
Population Dynamics / Noon et al. = Priority 1						
1	1/1	--	A1	Clarify relationship between annual CPUE index and true population size.	• Dudley et al. (2011a, 2011b, 2011c, 2012) implemented population estimation. • Goodman (2012) evaluated Population Estimation Program. • Valdez (2018a) evaluated relationship between CPUE and true population size (presented to PMWG 6/20/2018).	Remains unresolved
2	1/3	--	A2	Determine which age-specific vital rates (survival, reproduction, etc.) most affect population change.	• Goodman (2010) did deterministic dynamics of environmental correlates. • Miller (2012) performed sensitivity analysis as part of PVA. • Yackulic (2018) model in progress (presented to PMWG 12/12/2018).	Ongoing
3	1/3	--	A3	Estimate age-specific survival rates.	• Goodman (2009) estimated survival from quarterly comparisons of CPUE. • Miller (2012) reconciled survival rates from PVA. • Valdez (2018b) estimated survival of wild RGSM (presented to PMWG 12/12/2018).	Ongoing
4	1/3	22	A4, B3	Estimate size and age-specific fecundities of wild fish.	• Platania and Altenbach (1996) did clutch and batch production and fecundity estimates in a lab. • Caldwell et al. (2019) evaluated reproductive potential of captive RGSM. • Archdeacon?	Informatio n needed on wild RGSM

Number	Priority SP/PMWG	Hubert	Noon	Consolidated Recommendation	Progress (see Literature Cited)	Status
5	1/3	10	A5	Model relationships between demographic rates and hydrological factors (flow magnitude, duration, drying), abiotic factors (temp, turbidity, salinity), and biotic factors (predation, completion, prey).	• Miller (2012) related demographic rates to hydrological factors as part of PVA. • Archdeacon (2016) evaluated reduced spring flow. • Yackulic (2018) model in progress. • Walsworth and Budy (2020) model in progress. • Hatch and Cowley (2020)?	Ongoing
Population Dynamics / Noon et al. = Priority 2						
6	2/--	--	A6	Evaluate existence and strength of density-dependent factors that may limit population growth.	• Miller (2012) evaluated as part of PVA. • Goodman (2010) evaluated as part of PVA. • Yackulic (2018) model in progress.	Ongoing
Population Dynamics / Noon et al. = Other Important Studies						
7	Import/--	--	A7	Model potential effects of hatchery augmentation on population dynamics.	• Miller (2012) evaluated as part of PVA. • Archdeacon and Remshardt (2012). • Archdeacon (2015) provides annual reports on augmentation. • Yackulic (2018) model in progress. • Hatch and Cowley (2020)?	Ongoing
8	Import/--	--	A8	Determine if collection and translocation of salvaged RGSM during summery drying contribute to population dynamics.	• Archdeacon (2017) gave a presentation on Fish Rescue.	Ongoing
Reproductive Biology of Rio Grande Silvery Minnow / Noon et al. = Priority 1						
9	1/--	--	B1, E2	Develop and deploy "vertically-integrating" Moore egg collectors; determine vertical and horizontal distribution of RGSM eggs as a function of flow and location	• Porter (2018) designed a multi-level vertical egg collector.	Work initiated; more needed

Number	Priority SP/PMWG	Hubert	Noon	Consolidated Recommendation	Progress (see Literature Cited)	Status
10	1/--	--	B2, D2	Assess effect of environmental cues (flow, velocity, temp, flow change) on spawning onset and activity.	• Cowley et al. (2009) evaluated effect of salinity on specific gravity of eggs. • Krabbenhoft et al. (2014) evaluated phenology. • Valdez (2010, 2019, 2020a) evaluated temperature degree-days for hatching.	Ongoing
Age and Growth / Noon et al. = Priority 2						
11	2/--	--	C	Clarify annular marks on otoliths and firmly establish longevity of RGSM.	• Horwitz et al. (2018) used scales and otoliths for juveniles and adults. • Zipper et al. (2020a; 2020b) verified otolith age for larvae.	Unresolved
Physical Habitat Relations of RGSMs / Noon et al. = Other Important Studies						
12	Import/--	--	D1	Estimate spatial extent of habitat and hydraulic quality used by RGSM for key life-stages (spawning, larval, juvenile, adult).	• Tetra Tech (2014) evaluated habitat for occupied, feeding/rearing, spawning/ egg/larval habitat. • Walsworth and Budy (2020). • Colorado State University (2020)? • Yackulic (2020). • Hatch and Cowley (2020)?	Evaluation ongoing by several groups
13	Import/--	--	D3	Determine roles and relative contributions to fish production by age in channel and floodplain habitats.	• Tetra Tech (2014). • Walsworth and Budy (2020). • Colorado State University (2020)? • Yackulic (2020). • Hatch and Cowley (2020)?	Evaluation ongoing through modeling
14	Import/--	--	D4	Evaluate management potential for fish production (recruitment and survival of age 0 fish) in each reach if annual peak flow and available habitat is permanently limited below historic levels.	• Tetra Tech (2014). • Walsworth and Budy (2020). • Colorado State University (2020)? • Yackulic (2020).	Evaluation ongoing through modeling

Number	Priority SP/PMWG	Hubert	Noon	Consolidated Recommendation	Progress (see Literature Cited)	Status
Sampling Methodologies / Noon et al. Priority 1						
15	1/--	--	E1	Establish age composition of RGSM population, including application of distribution separation methods.	• Valdez (2018b) evaluated age composition using distribution separation methods (presented to PMWG 10/2/2018). • Winter (2018) provided a Bayesian analysis of von Bertalanffy growth function (presented to PMWG 12/12/2018).	Ongoing
16	1/--	--	E1	Evaluate size and age of fish captured by gear type with gear selectivity.	• Widmer et al. (2012) PP to Science Workgroup, 8/21/2012. • Gonzales et al. (2012) evaluated fyke-net catches. • Valdez et al. (2020b) evaluated gear selectivity (presented to PMWG 10/2/2018).	Ongoing
17	2/2	--	E3	Calculate revised CPUE values using most abundant high CPUE mesohabitats for assessment of trend in abundance at October sampling date.	• Valdez (2018c) computed CPUE at mesohabitat-specific levels (presented to PMWG 10/2/2018).	--
Sampling Methodologies / Hubert et al. Recommendations Sorted by PMWG Rankings = Priority 1						
18	--/1	1, 2, 3	--	Separate catch and effort data from small-mesh and fine-mesh seines and compute CPUE for each gear type and by age (larvae, age-0, age 1, age 2+).	• Dudley et al. (2020) have computed larval and standard seine CPUE annually since 2018.	Ongoing
19	--/1, 2	4, 5	--	Evaluate effect of zero catches on CPUE (zero as dry site, no fish captured).	• Dudley et al. (2020) have evaluated effect of zero catches on CPUE annually since 2018.	Ongoing
20	--/1, 2	6	--	Evaluate effect of sample design on zero CPUE.	Effect of sample design on zero CPUE has not been evaluated.	Not Initiated

Number	Priority SP/PMWG	Hubert	Noon	Consolidated Recommendation	Progress (see Literature Cited)	Status
21	--/3, 1	7, 8	--	Evaluate detection and catchability (*p*-hat) of RGSM in seines, including effect of environmental factors (turbidity, temp., substrate, depth, velocity, discharge) during sampling on CPUE.	• Archdeacon and Davenport (2013) evaluated detection and population estimation.	More work needed
23	--/1	11, 14, 17	--	Evaluate mixture model for computing RGSM CPUE, and other models, including Bayesian hierarchical models; consider using key drivers of mesohabitat variability (e.g., velocity, substrate, depth) to replace the mesohabitat factor in mixture models.	The mixture model has not been evaluated in this manner.	Not Initiated
24	--/1, 0	12, 13	--	Increase sample sites by 20-50 sites per reach, and evaluate effect on CPUE; add random sites to replace dry sites.	• Dudley et al. (2020) added sample sites starting in 2018. • Archdeacon et al. (2015) Compared fish communities at random and non-random sites.	Needs additional evaluation
Sampling Methodologies / Hubert et al. Recommendations Sorted by PMWG Rankings = Priority 1.5/2						
26	--/1.5	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.	This has not been implemented.	Not Initiated
25	--/2	16	--	Examine historical availability of mesohabitats relative to discharge. If linked, annual or monthly discharge may be surrogate for mesohabitat availability.	This has not been examined.	Not Initiated

Number	Priority SP/PMWG	Hubert	Noon	Consolidated Recommendation	Progress (see Literature Cited)	Status
Sampling Methodologies / Hubert et al. Recommendations Sorted by PMWG Rankings = Priority 3						
27	--/3	19	--	Implement studies using different sampling designs (multi-year, multi-site, before-after-control-impact [BACI]) to better understand population response to changes in river discharge, habitat rehabilitation projects, and mesohabitats.	This has not been implemented.	Not Initiated
28	--/3	21	--	Conduct stock-recruitment studies to determine how abundance of fall recruits relates to abundance of spring spawners.	• Miller (2012) • Walsworth and Budy (2020). • Yackulic (2020). • Hatch and Cowley (2020)?	Ongoing
30	--/3	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.	• This has not been implemented.	
Sampling Methodologies / Hubert et al. Recommendations Sorted by PMWG Rankings = Priority 0						
22	--/0	9	--	Evaluate recovery standards by gear, sample design, techniques, data analysis, and life stage.	Is evaluating recovery standards the charge of the PMWG?	Not Initiated
29	--/0	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 spring spawners and long-term risks to wild population.	Is this an issue for the Genetics Group?	Not Initiated

Executive Summary

Topic Area Title:

Age-specific survival of Rio Grande Silvery Minnow (RGSM)
Noon et al. (2017) recommendations A2 and A3.

Program Goal Relevance:

Provides an important demographic parameter to understand the numbers of fish surviving from one year to the next under different flow and environmental conditions.

Brief Summary of Available Literature:

Estimates of survival for RGSM were derived by Remshardt (2007) and Valdez (2010), and used by Miller (2012) to compute and infer age-specific survival in a RAMAS PVA (Table 1). Survival of RGSM by cohort was estimated by Goodman (2010) and used to resolve age-specific survival in a FORTRAN PVA. Yackulic (2020) preliminarily derived estimates of annual adult survival from an integrated population model. Estimated survival of RGSM has also been developed by Mike Hatch and David Cowley of New Mexico State University as part of an ongoing stock assessment model and PVA, but these estimates are not available at this time.

Remshardt (2007) estimated monthly survival of 0.662 for hatchery-reared fish released into the MRG in November 2004 and monitored through spring 2005. The fish were age-4 and were marked with VIE tags. Survival was estimated from the decline of marked fish in approximately monthly samples.

Valdez (2010) used the ASIR Population Monitoring dataset to compute mean monthly CPUE of all ages across reaches for years 1993–1997 and 1999-2010. He regressed these CPUEs over time in a "catch-curve" analysis that yielded an estimate monthly survival of 0.763 for wild fish, which was expanded to an annual survival rate of 0.039 (0.76312 = 0.039) for individuals 12 to 24 months of age. Valdez (2018) expanded the analysis to include mean monthly CPUE data for 1993-2017 (not 1998 and 2009) and derived monthly survival estimates for age-0 (mean = 0.736, range = 0.267-0.970), age-1 (mean = 0.740, range = 0.472-0.968), and age-2 (mean = 0.834, range = 0.583-0.976), which transform to mean annual survival of 0.03, 0.03, and 0.11, respectively. Annual adult survival (age 1+) was estimated at about 0.04.

Miller (2012) used the Remshardt (2007) and Valdez (2010) estimates of survival in his PVA model and reasoned that these monthly estimates represented some form of upper and lower bounds for the true value of this parameter. Miller (2012) noted that Remshardt (2007) did not see significant differences in survival among marked and unmarked fish in his 2005 augmentation study, and assumed that augmented fish (i.e., hatchery fish) were immediately subject to the same monthly rates of survival as the wild fish. Miller (2012) also assumed constant survivorship throughout the year, with the exception of an assumed lower survivorship of approximately 0.15 during the first month of life; he estimated survival of age-0 fish as (0.66211 = 0.007) x 0.15 = 0.0016 for fish up to 12 months of age. Miller (2012) then assumed a constant survival rate for age-1 (12-24 months of age) as 0.66212 = 0.007. Miller (2012) also assumed a constant annual survival for age-2 and age-3 individuals equal to 0.05, which was a value consistent with preliminary statistical analyses of survival (0.058) conducted by Goodman (2010) as part of PVA Workgroup activity.

Goodman (2009a) also used the 1993–1997 and 1999-2010 ASIR Population Monitoring dataset and estimated survival of RGSM by regressing inter-quarterly (Qn+1 vs Qn) CPUEs for all ages and reaches. Goodman (2010) determined a survival rate of 0.0580 for the 2007 cohort by plotting CPUE on a log scale and using the slope of the regression. Goodman (2009a) concluded that for years with a strong reproductive pulse, the survival rate to the pre-breeding census (early spring) ranges from about 0.03 to about 0.3; for years with reproductive failure, survival rate varies more widely, but the estimates may be less reliable for those years. On this basis, the Goodman concluded that PVA modeling should reasonably represent the cohort survival until the pre-breeding census as a random variable, with a mean around 0.1 and a mode around 0.05, and a longer right tail.

Table 1. Summary of Survival Estimates:

	Larvae	Age-0		Age-1		Age-2		Hatchery Age-?	
Citation	Monthly	Monthly	Annual	Monthly	Annual	Monthly	Annual	Monthly	Annual
Remshardt (2007)	--	--	--	--	--	--	--	0.662	0.01
Goodman (2009)	--	--	0.058	--	--	--	--	--	--
Hatch (2009)	--			0.09[b]				--	--
Valdez (2010)	--	0.763	0.04	--	--	--	--	--	--
Miller (2012)	0.15[a]	0.662	0.0016	0.662	0.007	--	0.05[a]	--	--
Valdez (2018)	0.502[c] (2016)	0.736	0.03	0.74	0.03	0.834	0.11	--	--
	0.472[c] (2017)	--	--	--	--	--	--	--	--
	0.301[d] (2017)	--	--	--	--	--	--	--	--
Yackulic (2020)	--	0.20 (0.15-0.25)[e]	--		0.04 (0.02-0.06)f			--	--

[a] estimated from model derivation.
b estimated from salvaged fish of all ages.
c estimated from floodplains.
d estimated from mainstem.
e approximate range derived from integrated model for June to October.
f approximate range of annual adult survival derived from integrated model.

Yackulic (2020), as part of the development of an integrated model for RGSM, derived estimates of annual adult survival (age-1+) each for the Angostura, Isleta, and San Acacia reaches. Altogether, estimates range from about 0.02 to 0.06 with a central distribution of about 0.04. Estimates of age-0 survival from June to October ranged from about 0.15 to 0.25 with a central distribution of about 0.20.

Mike Hatch (Personal communication, PVA Workgroup Meeting, 2009) provided an annual survival estimate of 0.09 for RGSM from salvaged fish, but no report was provided to detail the age of fish or method for deriving this estimate.

List the Uncertainties:

1. Is age-specific survival (larvae, ages 0, 1, 2+) different?
2. Is survival of older fish (age 2+) sufficiently high to enable “carry-over” from survival of older and presumably large and more fecund fish?

List the Hypotheses Identified from Literature:

1. Low spring-time survival of larval RGSM does not significantly increase population size, as measured by the October CPUE index.
2. Numbers of large and more fecund RGSM are not sufficiently large to significantly increase reproductive success.

Management Implication(s) of Hypotheses (if any):

1. Providing habitat and suitable conditions for survival of larvae can help to set cohort strength and the number of fish in the population.
2. Providing habitat and suitable conditions for survival of age-2+ fish could provide “carry-over” in the population so that large more fecund fish remain in years when reproduction and recruitment are otherwise low.

Potential Approaches to Test Hypotheses:

1. Estimate survival of larval RGSM from exponential function of density, or derived from modeling exercises.
2. Sample more intensively in spring to better determine the numbers of large RGSM present in the population in a given year.

Literature Cited:

Goodman, D. 2009. Rio Grande silvery minnow PVA: relating quarterly monitoring summaries to the synthesis. Draft Report, Montana State University, Bozeman, MT.

Goodman, D. 2010. Parameter estimation strategy for the PVA: I. Deterministic dynamics and environmental covariates. Draft Report, Montana State University, Bozeman, MT.

Miller, P.S. 2012. A RAMAS-Based Population Viability Model for the Rio Grande Silvery Minnow (Hybognathus amarus). A Project Funded by The Middle Rio Grande Endangered Species Act Collaborative Program. Final Report, Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN.

Noon, B., D. Hankin, T. Dunne, and G. Grossman. 2017. Independent Science Panel Findings Report: Rio Grande silvery minnow key scientific uncertainties and study recommendations. Prepared for the U.S. Army Corps of Engineers, Albuquerque District on Behalf of the Middle Rio Grande Endangered Species Collaborative Program. Prepared by GeoSystems Analysis, Inc. Albuquerque, NM. June 2017. Contract No. W912PP-15-C-0008.

Remshardt, W.J. 2007. Experimental augmentation and monitoring of Rio Grande silvery minnow in the Middle Rio Grande, New Mexico. Annual Report 2005. Final report to the Middle Rio Grande Endangered Species Collaborative Program and the U.S. Bureau of Reclamation, Albuquerque, New Mexico. 101 pp.

Valdez, R.A. 2010. Age, growth, and survival of Rio Grande silvery minnow. Power Point presentation to the Population Viability Analysis Workgroup. SWCA, Inc., Albuquerque, NM.

Valdez, R.A. 2018. Survival of Wild Rio Grande Silvery Minnow in the Middle Rio Grande. A Data Analysis Done for and in Collaboration with the Population Monitoring Workgroup. SWCA and New Mexico Interstate Stream Commission, Albuquerque, NM.

Yackulic, C.B. 2020. Rio Grande Silvery Minnow integrated population model. Power Point presentation to Population Monitoring Workgroup, February 26, 2020. U.S. Geological Survey, Flagstaff, AZ.

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Executive Summary: Consolidation of Mesohabitats for Monitoring RGSM

Source Recommendation

Noon et al. (2017) E3: "Calculate revised CPUE values as mesohabitat-specific levels and do not combine across mesohabitat types. The mesohabitat specific CPUE calculated for the most abundant high density mesohabitat type should be used for assessment of trend in abundance of the RGSM population at the October sampling date."

Program Goal Relevance

Revising the distribution and intensity of sampling across mesohabitat types at the sampling sites, along with other potential modifications, during the Population Monitoring Program (PMP) may improve the relationships associating computed catch per unit effort (CPUE) index values to the abundance and status of RGSM in the MRG. Such a revision also may enhance the cost-effectiveness of the PMP.

Literature Summary

Assessing the potential importance for and differences among in-channel habitat characteristics influencing RGSM presence during sampling includes consideration of the continual physical habitat variables of flow and depth. The PMP, perhaps logically, has focused on qualitative mesohabitat types as flow-depth "surrogates," such as implemented by the ongoing PMP, see below. To best enable the Population Monitoring Workgroup (PMWG) to evaluate this recommendation, the following includes summaries and sometimes direct quotes from a sample of reports linking RGSM occurrence to habitat flows, depths, and mesohabitat types.

Dudley and Platania (1996) provided the earliest extensive qualitative assessment RGSM habitat usage. Focusing on winter habitat, they reported that the majority (72.3%) of RGSM were caught in areas containing instream debris and consistently occurred over small substrata, at moderate depths, and in low velocity water. Subsequently, **Dudley and Platania (1997)** collected RGSM and other fish species during monthly sampling from July 1994 to June 1996 at two MRG sites, one each near Rio Rancho and Socorro. Habitat availability was determined at both sites monthly during the end of that monitoring period, from October 1995 to June 1996. They reported that RGSM exhibited differences in habitats use by size-class, with velocity being the strongest predictor of habitat use by size-class closely followed by depth; however, the correlation between these two physical variables clouded clear definition of the relative importance of each. They reported a bimodal distribution for depth use by RGSM, with individuals most commonly collected at depths <20 cm (0.7 ft) and 31-40 cm (1.1-1.3 ft), with few collected at depths >50 cm (1.6 ft). RGSM were abundant (86.5%) in areas having little or no water velocity (<10 cm/s; 0.3 ft/s), but only occasionally (11.0%) in areas of moderate velocity (11-30 cm/s; 0.4-1.0 ft/s) and rarely (0.8%) in habitats with water velocities >40 cm/s (1.3 ft/s). Most RGSM (91.3%) were collected over silt substrata. RGSM tended to be most abundant in low-velocity mesohabitats (debris piles, backwaters, and pools) and rarest in high velocity habitats (runs and riffles). Greater proportions of RGSM occurred in higher velocity mesohabitats (main and side channel runs) in summer than winter, with the population shifting from pool and backwater habitats in summer to habitats with instream debris piles in winter.

Summarizing available information, the **USFWS (2010, p. 11)** RGSM recovery plan states that the species "… only uses a small portion of the available aquatic habitat (**Platania 1993a, 1993b, [Dudley and Platania] 1997**).… [The species] is most often found in areas of low or moderate water velocity (e.g., eddies formed by debris piles, pools, backwaters, and embayments) and is rarely found in habitats with high water velocities, such as main channel runs, which are often deep and swift (**Dudley and Platania 1997, Watts et al. 2002, Remshardt 2007**). … [RGSM] augmentation monitoring throughout the middle Rio Grande (**Remshardt 2007, 2008**) reflected similar findings to other studies. No distinctions in habitat associations were observed between marked (hatchery) and unmarked (wild) [RGSM] … collections were positively associated with habitats that included low velocity and/or features that provide habitat diversity such as shorelines, debris, eddies, and submerged vegetation."

Implementation of mesohabitat sampling during the RGSM PMP has varied somewhat over time. The most recent approach is described in the 2019 PMP draft completion report (**Dudley et al. 2020, p.7**): "Fish were collected by rapidly drawing a two-person 3.1 m x 1.8 m small-mesh seine (ca. 4.8 mm [0.2 in]) through 18 discrete mesohabitats (< 1.5 m long [5 ft]). Runs were sampled four times at each site, as were shoreline pools (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. A 1.2 m x 1.2 m [2 ft x 2 ft] fine-mesh seine (ca. 1.6 mm [0.6 in]) was used to selectively sample shallow low-velocity mesohabitats for larval fish (two samples/site) from April to October. Mesohabitats with similar conditions, which did not exceed reasonable depths or velocities for efficient seining, were sampled regardless of flow conditions." This report also includes the following (**Dudley et al. 2020, p.51**): "A qualitative examination of the mesohabitats occupied by [RGSM] was conducted to obtain general information on the habitat-use patterns of this species. While the physical locations of mesohabitats shift around considerably over time, established sampling protocols for this study ensured that similar mesohabitats (i.e., depths and velocities) were sampled across years. We sampled a wide variety of mesohabitats to ensure balanced monitoring of the ichthyofaunal community and all life phases of Rio Grande Silvery Minnow. Population trends in the five different mesohabitats (BW, PO, RU, SHPO, SHRU [backwaters, pools, runs, shoreline pools, shoreline runs]) were quite similar over the study period (2002–2019), despite notable differences in the estimated densities of [RGSM] among mesohabitats. Densities were typically highest in lower velocity mesohabitats and lowest in higher velocity mesohabitats. General mesohabitat-use patterns observed during this study were similar to those documented during past studies (e.g., **Dudley and Platania 1997**)."

Bovee et al. (2008, p. 1) used two-dimensional hydraulic simulations to model hydraulic conditions for a range of discharges at three study sites in the MRG upstream from San Acacia Dam. Suitable habitat characteristics were defined for RGSM by consensus of a panel of experts and were "defined as areas having suitable hydraulic conditions alone and as areas having suitable hydraulics in association with large woody debris. Suitable hydraulic habitat for adults was reported as maximum at discharges between 40 and 80 cubic feet per second [cfs], which then declined rapidly at discharges larger than 150 [cfs]. When large woody debris was included in the definition of suitable habitat, discharges between 40 and 200 [cfs] provided maximum suitable habitat for adults. Juvenile hydraulic habitat was maximized at discharges between 20 and 80 [cfs], and hydraulic habitat associated with large woody debris was largest at flows between 40 and 150 [cfs]."

Technical staff from the U.S. Geological Survey, collaborating with USACE and USFWS personnel, evaluated the physical habitat characteristics and fish assemblage composition of available mesohabitats over a range of streamflows at 15 MRG sites during winter 2011–12 and summer 2012 (**Braun et al. 2015**). They reported that in the winter of 2011–12 RGSM were weakly associated with sand substrates, relatively moderate velocities, and relatively shallow depths; during summer 2012 they were associated with run mesohabitats, relatively high velocities, sand substrates, and relatively moderate depths. Of the four minnow species assessed, RGSM were collected from the narrowest range of depths (0.30–2.1 ft) during summer 2012 and the narrowest range of velocities in both winter 2011–12 (0.0–3.18 ft/s) and summer 2012 (0.02–1.51 ft/s). They also measured the physical characteristics of mesohabitats. Time constraints limited the number of mapped mesohabitat measured, but number of each mesohabitat type assessed was in proportion their abundance, with 20 mesohabitats assessed at each site. Measured depths and velocities varied greatly by mesohabitat type, site, and sampling period for both assessment periods. Applying area-weighting factors to the depths and velocities for sites assessed in both winter 2011–12 and summer 2012 typically had shallower mean depths and slower mean velocities during summer 2012, when discharges tended to be lower. Visual inspection of the box and whisker plots presented in their Figure 10 for measured depths and velocities for each of the eight type of mesohabitat assessed during each season at each sampling site assessed reveals considerable overlapping distributions for both physical parameters across all mesohabitat types within each site by season. [The data produced by this study, with perhaps other collected field data, are currently undergoing additional assessment by the USACE to evaluate approaches to (1) integrate its mesohabitat mapping with LiDAR, HEC-RAS, orthophotography, and other data sources to produce a geospatial model of in-channel habit; (2) investigate geospatial and temporal analyses for describing and presenting in-channel habitat information; and (3) develop techniques for integrating riparian floodplain and riverine habitat into single mapspace for the MRG (M. Porter, personal communication, email 4/9/2020).]

To assess how the distribution and availability of quality habitat for RGSM changed with flows at five MRG sites, **Tetra Tech (2014)** used, in part, geographic information system (GIS) methods to post-process outputs from an earlier project that collected in-channel data and conducted hydrodynamic simulation modeling (**Bohannan-Huston et al. 2004**). That earlier project included measurement of surface-water elevations and topographic surveys at eight sites along the Rio Chama and the MRG, completed during two visits per site. Each visit included 39 to179 geo-referenced, paired, in-channel flow and depth measurements using a survey-grade Global Positioning System (GPS) and total station theodolite. Those field data were then used by the earlier study to develop for each site a 1-foot contour topographic map of the riverbed and part of the adjacent floodplain. This topographic information was then used, in part, as input for RMA2 model to output of finite element mesh for each site composed of fine-scale triangular and quadrilateral elements with corner and mid-point nodes. As no comparable information is available for the MRG, Tetra Tech's obtained these early field data and modeled outputs. This information was then post-processed to develop site-specific habitat quality assessments, displayed using GIS, for RGSM at five of the earlier assessed sites in the MRG. The three habitat quality criteria used included

1. *Most commonly occupied habitat* (surface water areas averaging ≤ 1.5 feet (45 cm) depth and ≤ 1.5 ft/sec (0.45 m/sec) flow velocity, **USFWS, 2003, 2010**);
2. *Highest quality habitat for juvenile and adult feeding and larval rearing* (surface water areas averaging ≤ 1.5 feet (45 cm) depth and≤ 0.5 ft/sec (0.15 m/sec) velocity; **SEPM, 1984; Bovee, et al. 2008; USFWS, 2003, 2010**; and
3. *Highest quality habitat for spawning and for egg and larvae retention* (surface water and inundated floodplain areas averaging ≤ 1.5 feet (45 cm) depth and near 0 ft/sec. i.e., ≤ 0.05 ft/sec [1.5 cm/sec]) velocity; **Fisher et al., 1979; USFWS 2003, 2010**).

Highest quality modelled RGSM in-channel habitat conditions at the five MRG sites showed general patterns of declining quality with increasing flows, but each showed marked differences depending their in-channel geomorphic characterizations (**Tetra Tech 2014)**. The Bernalillo site had near maximum in-channel quality area for most commonly occupied habitat at about 350 cfs, which then declined sharply through modelled flows of 514 and 1,054 cfs until the modelled flow of 2,108 cfs when an ephemeral side channel re-connected yielding maximum habitat quality across all three criteria; the modeled flow of about 3,500 cfs then produced generally marked declines for all three assessed criteria. Modeled flows at the Central site showed highest in-channel habitat quality across all three criteria modeled flows of 197 and 462 cfs, with and marked declines in available in-channel habitat quality for all three quality criteria at modelled flows of 1,054 and 3,488 cfs. Areas of highest habitat qualities at the Bernardo site across all three criteria occurred for modeled flows of 334 and 605 cfs, with marked declines across all three criteria for modeled flows of 1,025, 2,218 and 3,500 cfs. The Bosque del Apache site had relatively abundant high-quality habitat across all four model flows from 256 to 3,097 cfs. Maximum in-channel quality habitat at the San Marcial site occurred for all three criteria at the modeled flow of 225 cfs; modeled flows of 625 to 2,753 cfs yielded declining projections of in-channel habitat quality for all three criteria. (The Tetra Tech report included RGSM habitat quality assessments using FLO-2D model output for inundated floodplains. Flows of approximately 5,000 cfs were estimated as required to inundate the floodplain along the Angostura to Isleta Reach; 3,500 cfs for the Isleta to San Acacia Reach; and 2,000 cfs for the reach from San Acacia to the San Marcial RR Bridge. As floodplain inundation is not relevant for consideration of in-channel mesohabitat assessments, these results are not summarized here.)

Coordinated and funded by the USBR (**Posner 2020**), Colorado State University, the University of New Mexico and American Southwest Ichthyological Researchers are currently conducting a multi-objective project linking morphodynamic and biological habitat conditions along the MRG. Eleven reach and linkage reports are planned. Of these, reports are currently available for the Isleta Diversion Dam to Rio Puerco reach (**Yang et al. 2019**), Rio Puerco to San Acacia Diversion Dam (**LaForge et al. 2019**), and San Acacia Diversion Dam to Escondida Bridge (**Doidge and Julien 2019**). Most of each report contains detailed assessments on how physical conditions of the MRG have changed since 1918 using historical information and aggradation/degradation lines (agg/deg lines) survey data. MRG sub-reaches included in these reports were distinguished and identified using channel slope changes using the agg/deg line data. The agg/deg line surveys are completed every ten years using photogrammetry earlier and LIDAR surveys more recently. The agg/deg lines are spaced approximately 500-feet apart and are primarily used to estimate sedimentation and morphological changes in the river channel and floodplain along the MRG. The Isleta report appendix also describes the approach used to assess RGSM habitat condition through the subreaches using GIS to integrate 1-D HEC-RAS analysis of agg/deg line measurements and USGS gage information with RGSM PMP results and habitat quality criteria. The HEC-RAS modeling integrates the channel width information from the agg/deg line surveys with corresponding USGS gage flows during the survey to fit a channel-depth trapezoid for each survey line extending from line to line [i.e., "an underwater prism" **(Doidge and Julien 2019, page 48)**]. These results were integrated with time and location corresponding RGSM PAP data and/or criteria values to map RGSM reach occupancy (use) and/or habitat quality using GIS. Criteria for RGSM habitat quality used in both the Isleta and Rio Puerco reach reports were a slight modification of the functional life-history criteria developed by **Tetra Tech (2014)**. The San Acacia reach reports used RGSM habitat quality based on lifestage (age) criteria presented by **Mortensen et al. (2019).** That report included three habitat quality criteria based water flow velocity and depth for three RGSM lifestages:

1. *Larvae* (<5 cm/s [<0.2 ft/s] and <15 cm depth [<0.5 ft]);
2. *Juveniles* (<30 cm/s [<1.0 ft/s] and 1-50 cm [0.03-1.6 ft]); and
3. *Adults* (<40 cm/s [<1.3 ft] and 5-60 cm [0.2-2.0 ft]).

For the Isleta reach, **Yang et al. (2019)** reported maximum spawning, rearing, and feeding habitat to occur at the modelled flow of approximately 3,500 cfs, i.e., when the floodplain inundated [a flow volume equivalent to that reported by Tetra Tech (2014)], whereas maximum good habitat [called "most commonly occupied" in the Tetra Tech (2014) report] occurred for the modelled flow of 600 cfs [similar to that reported by Tetra Tech (2014) for the Bernardo site]. **Doidge and Julien (2019)** noted that they considered the modeling done at low flows (<1,000 cfs) to be inaccurate. They also used RAS-Mapper for the 2012 LIDAR data, while comparisons across years were done using 1-D HEC-RAS techniques only. Reasonable correspondence between the two methods was shown. Considering results for the 2012 only, their modeling shows maximum RGSM habitat through the entire San Acacia reach for larva occurs at approximated 2,500 cfs, 4,500 for juveniles, and 5,500 cfs for adults **(Doidge and Julien 2019, page 57, Figure 51)**. [Note that **Tetra Tech (2014)** reported that floodplain inundation occurred at approximately 2,000 cfs for the reach from San Acacia to the San Marcial RR Bridge.] (Note also that USBR is also funding a project to Utah State University reportedly including considerations of mesohabitat relationships to RGSM, but information from that project is unavailable for this summary.)

For the PMWG, **Marcus (2019)** characterized and summarized the PMP data collect for RGSM using "regular gear" from February 1993 to October 2017. He primarily used histogram bins to group categories of collected data. Summing total RGSM collected by mesohabitat type for the period March 2002 to 2017 and the decade 2008-2017 showed that total numbers of RGSM collected varied by more than four orders of magnitude across the sampled mesohabitat types. He suggested that limiting the numbers of mesohabitat types sampled to those in the top three classifications having the greatest numbers of RGSM collected (mid-channel shoreline runs and pools plus backwaters, with the possible additions of the next four types with abundant RGSM recorded) might be done without meaningful loss of information, but cautioned that more advanced analyses of these results are needed to refine this conclusion. Other data summaries indicated that hauls with >50 RGSM collected occurred most frequently in mid-channel shoreline pools followed by backwater mesohabitats, with markedly and progressively lower collection numbers occurring for the other mesohabitat types. In turn, the greatest abundance of RGSM in hauls with >50 RGSM occurred in side-channel pools followed by backwater mesohabitats. In contrast, the two mesohabitats having the greatest frequency of hauls lacking RGSM were mid-channel runs and mid-channel shoreline runs.

Valdez (2013) described the attributes of the CPUE data produced by the PMP and evaluated the use of these data under several objectives, including (1) characterize the spatial and temporal distribution of the CPUE samples, including the statistical properties of the CPUE data particularly as related to precision and accuracy; (2) identify uses and limitations of the CPUE data; and (3) recommend aspects of a monitoring program for the RGSM based on these findings. He reported that the high level of heterogeneity in the collection data indicated a mismatch between the spatial distribution of sampling units (i.e., seine hauls) and the contagious distribution of RGSM. Here he noted that RGSM are usually found as large concentrations (i.e., schools) in preferred habitats that are disconnected and uncommon. He also stated that the placement of seine hauls proportional to mesohabitat areas misses many of the small and uncommon habitats occupied by the fish, producing a disproportionately large number of zero catches. CPUE for RGSM was considerably higher in certain mesohabitat types. He concluded that there is not sufficient information at this time to develop a reliable, precise, and unbiased monitoring program for the RGSM. Nevertheless, his assessment indicated that the spacing and location of sampling units (i.e., seine hauls) should be congruous with the spatial distribution of the RGSM, which is strongly allied to specific mesohabitat types, especially during the period of least abundance variability (i.e., September through November). While the current monitoring design uses a stratified fixed-site design that samples mesohabitat types in proportion to their area at the same locations during each sampling event, he suggested that the PMP design would be improved upon using a stratified random-site design or a systematic random design.

Recommendation E3 from **Noon et al. (2017)** suggested evaluating individual mesohabitat types and not combining types for computing mean annual CPUE. Intending to specifically address this recommendation and working with the PMWG, **Valdez (2018)** prepared another report to specifically assess catch-per-unit-effort estimates from the PMP by individual mesohabitat types. Using the PMP data, CPUEs were calculated for each of the most abundant mesohabitat types with highest fish density to determine whether the trend in abundance of RGSM could be assessed using only one or a few of these mesohabitat types. Only one mesohabitat type (MCPO) yielded a distribution and magnitude of CPUEs not significantly different from that computed using all mesohabitats types, but the sample size included only 283 seine hauls. To determine how the number of samples might be increased using subsets of the 22 mesohabitat types sampled during 2002-2016, he found that CPUE estimates computed using RGSM collections from only the main channel pools and backwaters produced mean annual October CPUEs not significantly different (Kolmogorov-Smirnov [K-S] test; $p > 0.05$) from CPUEs computed using all mesohabitat types, but the numbers of samples (seine hauls) in both of these mesohabitats were still markedly less that an order of magnitude fewer than the total from across all mesohabitats included in the PMP during the same period. Additional analyses showed that combining the six mesohabitat types with highest CPUEs (five pool types plus backwaters) could be used to produce larger sample sizes. For example, combining mesohabitat samples for the annual October CPUEs produced for the combined five pool types (n = 1,496), and for the combined five pools types plus backwaters (n = 1,972). Both of these produced CPUEs not significantly different (K-S test; $p > 0.05$) from those computed CPUEs using all mesohabitat types (n = 5,563). This demonstrated that either of these combinations can produce the same pattern of CPUEs with 73% and 65% fewer samples, respectively. But, he noted that unequal samples of backwaters over time or space could inflate and bias CPUEs. Of importance, the reduced numbers of samples using only the available pools plus backwaters reduced the precision (i.e., coefficient of variation) of CPUE by about 27% and 19%, respectively for the two estimators of pools only and of pools plus backwaters. However, simulating an equal number of 400 samples per year showed an improved precision of 29% and 34%, respectively, over the simulated CPUEs drawn from all mesohabitats. Additional discussion was presented to address issues related to potential limited occurrence for the six mesohabitat types by sampling site and over years, also an approach was suggested to potentially reduce the numbers seine hauls needed for RGSM at differing densities.

List the Uncertainties:

1. Is the ongoing use of multiple diverse mesohabitat-based sampling for the PAP the most appropriate basis for assessing RGSM population trends in along the MRG? Most habitat use assessments used as a basis for defined habitat suitability for RGSM focus on the physical habitat characteristic of flow and depth. In contract the PAP sampling, beginning at least with Dudley and Platania (1997), has used mesohabitat types as a surrogate for depth and velocity. Yet, physical conditions measured for mesohabitats presented by Braun et al. (2015) clearly show considerable overlap in flow and depth measurements among all of the mesohabitat types they assessed. From this, questions may be raised on whether multiple diverse mesohabitat-based sampling as currently employed by the PAP are appropriate or, indeed, are reasonable surrogates for habitat flows and depths apparently favored by RGSM. If the current PAP based on multiple diverse mesohabitat-based sampling do not reasonably, consistently, or agreeably characterize depth and flow (i.e., habitat suitability) most favored by RGSM, what is an appropriate alternative?
2. Is it appropriate, as apparently is the current practice if the PMP, to weight sampling of mesohabitats more toward those that have been frequently flow and depth characteristics

reported to provide conditions less suitable for, less favoring RGSM presence, which produce biased low CPUE index values for RGSM occurrences?

3. What is the appropriate habitat scale to assess most suitable habitat quality for RGSM? RGSM individuals and schools likely are ever changing visitors to habitats of varying qualities. The reviewed assessments occurred over a range of scales. Favorable feeding habitats used by adults and juveniles are likely exist mostly at the microhabitat scale where suitable food resources can accumulation for this benthic feeding fish species. Quieter flow habitats include shoreline and backwater areas and, particularly during higher flows, troughs between bed ripples and dunes. Most favorable spawning and early rearing habitat for larvae likely are provided by larger habitat floodplain areas, whereas good or most commonly occupied habitat for larger RGSM could involve even larger in-channel and floodplain areas. The Tetra Tech (2014) report assessed quality in-channel RGSM habitat using modeled depths and flows developed using one-foot topographic bed-data contours, areas close a microhabitat scale. Larger mesohabitat-scale sampling is used during the PAP and other RGSM sampling studies (e.g., Braun et al. 2015). And, the ongoing USBR studies define quality RGSM habitat areas using 500-m long sub-reaches and modeled smooth-bed underwater prisms, which may be considered a macrohabitat scale. The smaller scale assessments suggest that the best in-channel habitat for RGSM occur typically over an incremental scale in 100s cfs until the floodplains connect, whereas the largest scale modeling assessments concluded that model flows of <1,000 cfs to be inaccurate and that the best RGSM habitat quality occurs at modelled flows of >2,500, in effect, after floodplains connect (Doidge and Julien 2019).
4. What more assessment is needed for recommendation E3 posed by Noon et al. (2017)? Marcus (2019) and Valdez (2013, 2018) have summarized and assessed the PAP RGSM collection data associated with mesohabitats sampled. Valdez (2018) specifically assessed these data in the manner specified under the E2 recommendation from Noon et al. (2017) and has made recommendation on next steps.
5. Will next step recommendations present in Valdez (2018) be followed? The combination of mesohabitat types (PO/BA/ED; RU/RI/FL) recommended by Valdez (2018) are being implemented by Yackulic (2020) in a RGSM Integrated Model.
6. Can the PAP be modified in a manor to produce potentially more reliable CPUE index values for RGSM population trends, which may also be more cost effective for the MRGESCP?

List the Hypotheses Identified from Literature:

1. Based on the PMP as currently implemented (e.g., Dudley et al. 2020): All mesohabitat types currently sampled and in the proportioned sampled during the PMP are necessary and appropriate for the calculation of CPUE index values to characterize the status of RGSM population in the MRG.
2. The PMP can be modified to emphasize a subset of the currently defined mesohabitat types to compute CPUE index values to track RGSM trends, while continuing to provide a meaningful relationship and continuity to the long history of data from the RGSM PMP.

Management Implication(s) of Hypotheses (if any):

The MRGESCP and its collaborating member will potentially obtain improved data quality on RGSM trends in the MRG and potentially at less cost.

Potential Approaches to Test Hypotheses:

Follow recommendations provided in Valdez (2013, 2018) and then assess results relative to historical RGSM PAP collections.

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Middle Rio Grande Endangered Species Collaborative Program
Population Monitoring Work Group (PMWG)
2020 Work Plan

The Population Monitoring Workgroup (PMWG) is charged by the Executive Committee (EC) of the MRGESCP with evaluating the monitoring program and demographics for the Rio Grande Silvery Minnow (RGSM) in the Middle Rio Grande, in accordance with three tasks: (1) conduct a workshop on CPUE methodology, (2) review the fish population monitoring plan, and (3) update the monitoring plan. Task 1 was completed in 2016, and Task 2 is currently being executed by the PMWG.

The PMWG plans to conduct and complete the following tasks in 2020:

Task	Subtask	Target Completion Date
1. Integrate and prioritize 22 recommendations from two science panels	1a. Consolidate recommendations 1b. Complete Executive Summaries on six to eight recommendations to aid in the ranking and implementation processes	1a. February 18, 2020 1b. December 20, 2020
2. Develop and review integrated RGSM model	2a. Complete base model 2b. Review model, conduct sensitivity analyses, and run scenarios 2c. Complete draft working model	2a. February 26, 2020 2b. September 15, 2020 2c. December 20, 2020
3. Develop draft report of Integrated RGSM model and preliminary results	3a. Complete Preliminary Draft Report on Integrated RGSM Model	3a. December 20, 2020
4. Reports to EC	4a. Draft Progress Report to EC 4b. Present preliminary findings to EC 4c. End of Year Report to EC	4a. May 1, 2020 4b. May EC Meeting 4c. Last 2020 EC Meeting