Population Monitoring Work Group Meeting

February 26, 2020

Meeting Materials:

Agenda

Minutes

Draft 1 Assimilation and Synthesis of Information and Data Related to the RGSM: Proposed Outline of Topics for the PMWG Report [read-ahead, draft]

Draft 1 Table 1. Consolidated Recommendations From the Hubert et al. (2016) and Noon et al. (2017) Science Panels [read-ahead, draft]

Draft 1 Literature Cited [read-ahead, draft]

PMWG Meeting [presentation]

RGSM Integrated Population Model [presentation]

Summary Table of Stakeholder Responses to Questions About the Integrated RGSM Model [read-ahead]

Draft 1 Appendix A: Tables of Science Panel Recommendations [read-ahead, draft]

Middle Rio Grande Endangered Species Collaborative Program

Est. 2000

Population Monitoring Work Group (PMWG)
February 26, 2020
8:30 AM – 4:00 PM

U.S. Bureau of Reclamation
555 Broadway Blvd NE, Albuquerque, NM

Call-in Information:
712-451-0011; Access code 141544#

Meeting Agenda

8:30 – 8:45	**Welcome, Introductions, Agenda Review, Meeting Notes** ➢ **Decision:** Approval of February 26, 2020 meeting agenda ➢ **Decision:** Approval of November 6, 2019 PMWG meeting minutes	*PMWG Co-chairs*
8:45 – 9:00	**2020 Work Plan**	*PMWG Co-chairs*
9:00 – 10:00	**Progress on Integrated Population Model**	*Charles Yackulic, USGS*
10:00 – 10:15	**Break**	
10:15 – 12:00	**Progress on Integrated Population Model (cont'd)**	*Charles Yackulic, USGS*
12:00 – 1:30	**Lunch** (on own)	
1:30 – 2:30	**Consolidation of Science Panel Recommendations**	*Rich Valdez, Mike Marcus*
2:30 – 3:00	**PMWG Report on Assimilation and Synthesis of Information and Data**	*Rich Valdez*
3:00 – 3:15	**Break**	
3:15 – 3:30	**Status of Data** • Program Portal • Other data	*Shay Howlin, PST*
3:30 – 3:45	**Program Structure Planning** • Functions and tasks of the PMWG	*Facilitated discussion*

- Discussion how those functions and tasks will fit under new Program structure

3:45 – 4:00	**Wrap-Up** • RGSM Habitat Suitability Modeling brown bag presentation in April *(date TBD)* • Action Items • Next Meeting	*PMWG Co-chairs*
4:00	**Adjourn**	

Population Monitoring Work Group (PMWG)
February 26, 2020

Meeting Decision Log and Action Items

Decisions:

- ✓ Approval of February 26, 2020 meeting agenda with amendments:
  - o Move the work plan discussion to the afternoon before the Program structure conversation
  - o Switch the order of Consolidation of Science Panel Recommendations and PMWG Report on Assimilation and Synthesis of Information and Data
- ✓ Approval of November 6, 2019 PMWG meeting minutes

Action Items:

WHO	WHAT	BY WHEN
Program Support Team (PST)	Doodle Poll the PMWG to schedule a meeting during one of the following weeks: March 23, April 6, April 13	February 28, 2020
Charles Yackulic	Revise presentation to include legends and titles on all charts	March 3, 2020
PST	Distribute Charles Y.'s revised presentation slides	ASAP after receiving slides
PST	Send out invitations to the Zotero library	February 28, 2020
PST	Develop a draft template for the 14 topical executive summaries	March 18, 2020
Charles Y.	Look further at data from the 1990s regarding egg production	Prior to next meeting

- ➢ Next Meeting: TBD

Meeting Minutes

Welcome, Introductions, Agenda Review, and Meeting Notes

The PMWG co-chairs, Rich Valdez, SWCA, and Joel Lusk, U.S. Bureau of Reclamation, opened the meeting and led introductions. They reviewed the agenda and the minutes from the November 2019 meeting.

- ➢ **Decision**: Approval of February 26, 2020 PMWG meeting agenda with amendments
- ➢ **Decision**: Approval of November 6, 2019 PMWG meeting minutes

Progress on Integrated Population Model

Rich V. shared a paper, "A quantitative life history of endangered humpback chub that spawn in the Little Colorado River: variation in movement, growth, and survival,"[1] as an example of the type of work that can come out of the integrated stock assessment model being developed in the PMWG.

[1] Yackulic, C. B., Yard, M. D., Korman, J., & Haverbeke, D. R. (2014). A quantitative life history of endangered humpback chub that spawn in the Little Colorado River: variation in movement, growth, and survival. Ecology and evolution, 4(7), 1006–1018. https://doi.org/10.1002/ece3.990

Charles Yackulic, U.S. Geological Survey, presented the progress on the model, and answered questions. He informed the group that all the code for the model will be available for the group to look at. During the discussion, the following points were made:

Model development

- Charles Y. did not have the data needed to explore capture probability related to mesohabitat type. The population estimation data did not reveal a significant difference in habitat types. A study will likely have to be designed specifically for that purpose.
- Charles Y. is exploring how to scale the model up based on the underlying abundance model. Having another dataset that looks at habitat and availability at a finer scale would be helpful.
- In Charles Y.'s experience, a negative binominal model is sufficient to adequately address inflated zeroes. It is possible to compare the negative binomial with simulated data to determine if a mixture model is needed.
- One of the next steps in model development is determining the appropriate flow covariate(s) to use.
- The model estimates abundance even when there was no sampling data, and data points were not included if there was too high a discharge in April, as that impacts ability to sample.
- If there is no data available, then the model assumes survival is like other intervals.

Spatial relationships

- There is a recent paper on RGSM dispersal, "Dispersal of Stocked Rio Grande Silvery Minnow (*Hybognathus amarus*) in the Middle Rio Grande, New Mexico."[2]
- The movement data being collected by Utah State University (USU) will be much higher quality data than anything currently in the model. The group should consider revisiting movement once USU has completed its analysis.

Adult survival and abundance

- The model is currently not showing much difference between years in adult survival. This could be either because (a) variability between years is mainly related to sampling, or (b) some of that variability is being erased using random effects analysis.
- Charles Y. is not seeing evidence of survival being linked to density dependence, but is seeing evidence that recruitment is linked to density dependence.
- Charles Y. expects the numbers of adult abundance to be a bit lower than just expanding catch per unit effort (CPUE) numbers, as CPUE is based on samples concentrated in pools.

RGSM reproduction

- Charles Y. has been assuming stocked fish have a lower fecundity than wild-spawned fish due to their smaller size.
- The model includes a parameter to take into account the survival of stocked fish impacting overall fecundity of stocked fish.
- The model wants to go higher than the 3000 maximum offspring per adult in the current parameters, which is based off of laboratory studies. This could be for two reasons: (a) RGSM can have more offspring in the wild so the laboratory estimates are on the low end, or

[2] Platania, S. P., Mortensen, J. G., Farrington, M. A., Brandenburg, W. H., & Dudley, R. K. (2020). Dispersal of stocked Rio Grande silvery minnow (*Hybognathus amarus*) in the Middle Rio Grande, New Mexico. The Southwestern Naturalist 64(1), 31-42. https://doi.org/10.1894/0038-4909-64-1-31

(b) there is something not being taken into account regarding adult abundance, particularly at low abundances. There are a couple of time periods in the 1990s which the model struggles with.

- Spawning later in the season may increase the numbers of eggs produced that year. Fish may be forced to spawn before they have achieved maximum readiness due to the spring runoff.

➢ **Action Item**: Charles Y. will look further at the data from the 1990s regarding egg production

RGSM augmentation

- RGSM have been stocked in February a few times, but that will not be happening again because there has not been any significant difference. Most RGSM are stocked in November after the October sampling, and not near sampling sites. If there are a large number of fish to be stocked, there will be two batches: one in October and one in November.
- The model is treated as three different time periods: before stocking, when stocking was occurring but without standardized timing and marking of fish, and stocking at standardized times and markings.
- The model has an estimated parameter for initial stocking mortality and then after that, assumes stocked fish behave like other age-1 fish. This assumption is based on mark-recapture studies and the survival of wild fish.

Habitat

- Charles Y. is lumping habitat types into pools and runs/riffles. Backwaters are considered a pool for the model.
- If there are enough data points on the relationship of depth and velocity to mesohabitat type, a statistical relationship can be developed.
    - There was a data collection effort completed in 1996 looking at habitat characteristics. There are notes on discharge measurements and the cross section surveys. However, these exist only in paper copy and will require a large data entry effort.
- While Charles Y. does think there are different discharge-habitat relationships by reach, there are not enough data to evaluate that.

The group then discussed how the integrated stock assessment model will or can interact with the other modeling efforts that are ongoing. Charles Y. noted that he has talked with some of the other modelers. Several participants supported having those developing the models meet together in a technical workshop to discuss the different efforts, the different management actions and options that could be implemented in the Middle Rio Grande, and options for how the different models can work together. The timing of this potential workshop will have to be determined, based on contracts and the model development schedule.

Another participant suggested the need for a workshop to discuss what the group wants out of the integrated stock assessment model.

Survey Results

Joel L. reminded PMWG participants that a survey was sent to managers in the fall 2019 that explained the types of management questions they would like the integrated stock assessment model to address. He took the survey responses and binned them into categories. Based on the categories, Charles Y. informed the group that the model:

- Could partially be used to evaluate water management actions, to the degree that data can be separated out, and just to make predictions and forecasts
- Could mostly address questions related to population parameters, dynamics, or recovery
- Could mostly quantify various effects to population or individuals
- Is not currently treating reach metapopulations as distinct, but the group may want to look more at small population problems
- Can look at habitat in two different ways:
  - Residuals on the flow relationship, which he did not recommend
  - Within the context of a hypothesis of what flows matter, by reconstructing how much floodplain inundation would occur at a certain flow
    - There are a few ongoing or existing efforts looking at the relationship between floodplain inundation, elevation, and flow. Though a few participants noted that the area of inundated habitat has not been found to scale well with any CPUE, recruitment, or flow metrics.

Consolidation of Science Panel Recommendations & PMWG Report on Assimilation and Synthesis of Information and Data

Rich V. shared a history of some of the highlights of the PMWG and the RGSM Population Monitoring Program. He stated there have been a lot of good conversations and efforts, but they have not been archived. He introduced the concept of developing topical issue papers to the PMWG.

Mike Marcus, Assessment Payers Association of the Middle Rio Grande Conservancy District, provided some history in past efforts in the Program to synthesize and compile data, including the Water Acquisition and Management (WAM) committee and a habitat restoration plan for the Middle Rio Grande. He informed the group that he and Rich V. had taken the panel recommendations from both the Noon and Hubert reports and consolidated them by topic – these are the fourteen areas that are being proposed for developing papers around.

The group discussed the utility of developing papers, and agreed to focus these into executive summaries for each of the 14 topic areas, summarizing the published literature and noting alternative hypotheses where there are differences of opinion. During the conversation, the following points were made about the process in developing these executive summaries:

- There should be some conversation and review on each paper before they are finalized
- In prioritizing the topic areas for development, some of the topics are more informative in developing the integrated stock assessment model, and should likely be done first
- These executive summaries, by identified alternative hypotheses, could feed directly into development of Program activities and recommended studies

The group then walked through an example, Age Composition, and outlined what the executive summary might look like.

- ➢ **Action Item:** Kevin McDonnell and Catherine Murphy, PST, develop a draft template for the executive summaries

Status of Data

Shay Howlin, PST, informed the group that she has been working with Ashley Tanner to take over the responsibility around the datasets used by the group. The PST and the U.S. Army Corps of

Engineers have been working with the U.S. Geological Survey on getting the following datasets onto the Program Portal:

- Data collected by ASIR, including the Population Monitoring Program, Population Estimation, and Reproductive Monitoring
- RiverEyes data
- Habitat restoration compilation map, which are geospatial data with extensive attribute data
- Hink and Ohmart vegetation maps

In addition to the datasets above, the group suggested the following also be included on the Portal:

- RGSM augmentation – Thomas Archdeacon, U.S. Fish & Wildlife Service, has those data available
- RGSM salvage data – Thomas A. has these data in multiple spreadsheets, and they require a bit of work to get them useable
- RGSM egg data – These are collected by four different groups (ASIR, Albuquerque-Bernalillo County Water Utility Authority, the BioPark, and SWCA contracted through the N.M. Interstate Stream Commission [NMISC]) and could be standardized and compiled
- The Field Data Collection Report from Winter 1996 – These includes survey data that can inform habitat characterizations. These data are only in hard copy and require a lot of data entry and processing.
- Floodplain habitat monitoring data – This has been collected by SWCA under contract with NMISC

Next Steps

- Due to time, the conversations about Program structure and the PMWG's 2020 Work Plan will be on the next meeting's agenda.
- Agenda items for the next meeting:
    - PMWG 2020 Work Plan
    - Program structure
    - Executive Summary template
    - Next steps on the 14 topic documents

➢ **Action Item**: The PST will send out a doodle poll to schedule the next meeting for late March/April

Participants
Thomas Archdeacon, U.S. Fish and Wildlife Service
Trevor Birt, N.M. Interstate Stream Commission
Lynette Giesen, U.S. Army Corps of Engineers
Grace Haggerty, N.M. Interstate Stream Commission
Brian Hobbs, U.S. Bureau of Reclamation
Mo Hobbs, Albuquerque-Bernalillo County Water Utility Authority
Shay Howlin, Program Support Team
Debbie Lee, Program Support Team
Joel Lusk, U.S. Bureau of Reclamation
Mike Marcus, Assessment Payers Association
Anne Marken, Middle Rio Grande Conservancy District
Kevin McDonnell, Program Support Team
Catherine Murphy, Program Support Team
Michael Porter, U.S. Amy Corps of Engineers
Ashlee Rudolph, U.S. Bureau of Reclamation
Rich Valdez, SWCA
Charles Yackulic, U.S. Geological Survey
Stephen Zipper, SWCA

Assimilation and Synthesis of Information and Data Related To the Rio Grande Silvery Minnow

Proposed Outline of Topics for the Population Monitoring Workgroup Report

Draft 1: February 18, 2020

1. Relationship of CPUE and True Population Size of RGSM
2. Age-Specific Survival of RGSM
3. Size and Age-Specific Fecundity of RGSM
4. Effect of Augmentation on RGSM Population
5. Contribution of Salvaged RGSM to Population Dynamics
6. Effect of Environmental Cues on Spawning Onset and Activity
7. Age Composition of RGSM Population
8. Spatial Extent of Habitat and Hydraulic Quality Used by RGSM
9. Selectivity of Gears Used to Sample RGSM
10. Consolidation of Mesohabitats for Monitoring RGSM
11. Effect of Environmental Factors on Seine Capture Probability
12. Effect of Increased Sample Size on RGSM Monitoring
13. Mixture Model and Alternatives for Computing RGSM CPUE
14. Movement of RGSM

Table 1. Consolidated 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

Literature Cited

Archdeacon, T.P., and W.J. Remshardt. 2012. Observations of hatchery reared Rio Grande silvery minnow using a fishway. North American Journal of Fisheries Management 32:648–655.

Archdeacon, T.P., and S.R. Davenport. 2013. Detection and population estimation for small-bodied fishes in a sand-bed river. North American Journal of Fisheries Management 33:446–452.

Archdeacon, T.P. 2015. Rio Grande silvery minnow augmentation in the middle Rio Grande, New Mexico: annual report 2014. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Archdeacon, T.P., K.R. Henderson, T.J. Austring, and R.L. Cook. 2015. Comparison of fish communities at random and non-random sites in a sand-bed river. North American Journal of Fisheries Management 35:578–585.

Archdeacon, T.P. 2016. Reduction in spring flow threatens Rio Grande Silvery Minnow: Trends in abundance during river intermittency. Transactions of the American Fisheries Society 145:754–765.

Archdeacon, T.P. 2017. Rio Grande silvery minnow rescue. Power Point presentation. New Mexico Fish and Wildlife Conservation Office, U.S. Fish and Wildlife Service, Albuquerque, NM.

Budy, P. and T.E. Walsworth. 2019. Review of the "Analytical framework for evaluating the proposed water management and maintenance actions on Rio Grande silvery minnow, southwestern willow flycatcher, and yellow-billed cuckoo and their critical habitats" with recommendations for future analytical considerations. USGS Utah Cooperative Fish and Wildlife Research Unit Report UCFWRU (1) 2019: 1-38.

Caldwell, C.A, H. Falco, W. Knight, M. Ulibarri, and W.R. Gould. 2019. Reproductive potential of captive Rio Grande silvery minnow. North American Journal of Aquaculture 81:47–54.

Colorado State University. 2020. Flow to habitat relationships?

Cowley, D.E., J.C. Alleman, R. Sallenave, R.R McShane, P.D. Shirey. 2009. Effects of salinity on specific gravity and viability of eggs of a North American minnow (Cyprinidae). Scientia Marina, October 2009, 47-58, Barcelona, Spain.

Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2011a. Rio Grande silvery minnow population estimation program results From October (2006-2008). American Southwest Ichthyological Researchers, L.L.C., 10 February 2011. A Middle Rio Grande Endangered Species Collaborative Program Funded Research Project. U.S. Bureau of Reclamation, Albuquerque, NM.

Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2011b. Rio Grande silvery minnow population estimation program results from October 2009. American Southwest Ichthyological Researchers, L.L.C., 10 February 2011. A Middle Rio Grande Endangered Species Collaborative Program Funded Research Project. U.S. Bureau of Reclamation, Albuquerque, NM.

Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2011c. Rio Grande silvery minnow population estimation program results from October 2010. American Southwest Ichthyological Researchers, L.L.C., 31 May 2011. A Middle Rio Grande Endangered Species Collaborative Program Funded Research Project. U.S. Bureau of Reclamation, Albuquerque, NM.

Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2012. Rio Grande silvery minnow population estimation program results from October 2011. American Southwest Ichthyological Researchers, L.L.C., 31 May 2012. A Middle Rio Grande Endangered Species Collaborative Program Funded Research Project. U.S. Bureau of Reclamation, Albuquerque, NM.

Dudley, R.K., S.P. Platania, and G.C. White. 2020. Rio Grande silvery minnow population monitoring during 2019. American Southwest Ichthyological Researchers, L.L.C., Albuquerque, NM.

Gonzales, E.J., G.M. Haggerty, and A. Lundahl. 2012. Using fyke-net capture data to assess daily trends in abundance of spawning Rio Grande silvery minnow. North American Journal of Fisheries Management 32:3, 544-547.

Goodman, D. 2009. Rio Grande Silvery Minnow PVA: Relating quarterly monitoring summaries to the synthesis. Report to the Population Viability Analysis Workgroup. Montana State University, Bozeman.

Goodman, D. 2010. Parameter estimation strategy for the PVA: I. Deterministic dynamics and environmental covariates. Report to the Population Viability Analysis Workgroup. Montana State University, Bozeman.

Goodman, D. 2012. The ASIR population estimation program. Report to the Population Viability Analysis Workgroup, Montana State University, Bozeman.

Hatch, M.D., F. Abadi, W.J. Boeing, S. Lois, M.D. Porter, and D.E. Cowley. 2020. Reduced adult survival probability drives endangerment of fish species globally. In Review.

Horwitz, R.J., D.H. Keller, P.F. Overbeck, S.P. Platania, R.K. Dudley, and E.W. Carson. 2018. Age and growth of Rio Grande silvery minnow *Hybognathus amarus*, an endangered, short-lived cyprinid of the North American Southwest. Transactions of the American Fisheries Society 147:265–277.

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.

Krabbenhoft T.J., S.P. Platania, and T.F. Turner. 2014. Interannual variation in reproductive phenology in a riverine fish assemblage: implications for predicting the effects of climate change and alteration of flow regimes. Freshwater Biology 59, 1744-1754.

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.

Platania, S.P., and C.S. Altenbach. 1996. Reproductive ecology of Rio Grande silvery minnow *Hybognathus amarus*: clutch and batch production and fecundity estimates. Final Report to the U.S. Army of Corps of Engineers, Albuquerque, New Mexico.

Porter, M.D. 2018. Vertical, multi-level egg collector. U.S. Army Corps of Engineers, Albuquerque, NM.

Tetra Tech, Inc. 2014. Ecohydrological relationships along the Middle Rio Grande of New Mexico for the endangered Rio Grande silvery minnow. Final Report, Tetra Tech, Inc., Albuquerque, NM.

Valdez, R.A. 2010. Age, growth, survival, and hatching dates of Rio Grande silvery minnow in the Middle Rio Grande, New Mexico. A data analysis done for and in collaboration with the Population Monitoring Workgroup. SWCA and New Mexico Interstate Stream Commission, Albuquerque, NM.

Valdez, R.A. 2018a. Relationship between annual catch-per-unit-effort index and true population size of Rio Grande silvery minnow, Draft 2. A data analysis done for and in collaboration with the Population Monitoring Workgroup. SWCA and New Mexico Interstate Stream Commission, Albuquerque, NM.

Valdez, R.A. 2018b. 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.

Valdez, R.A. 2018c. Catch-per-unit-effort of Rio Grande silvery minnow at mesohabitat-specific levels. A data analysis done for and in collaboration with the Population Monitoring Workgroup. SWCA and New Mexico Interstate Stream Commission, Albuquerque, NM.

Valdez, R.A., G.M. Haggerty, K. Richard, and D. Klobucar. 2019. Managed spring runoff to improve nursery floodplain habitat for endangered Rio Grande Silvery Minnow. Ecohydrology DOI: 10.1002/eco.2134.

Valdez, R.A., S.A. Zipper, S.J. Kline, and G.M. Haggerty. 2020a. Use of restored floodplains by fishes of the Middle Rio Grande, New Mexico, USA. Ecohydrology, *In Review*.

Valdez, R.A., M.D. Porter, E. Gonzales, S.A. Zipper, and G.M. Haggerty. 2020b. Selectivity of gear used to sample an endangered fish species in a western sand-bed river. Unpublished Manuscript.

Walsworth, T.E. and P. Budy. 2020. DRAFT: Hydrologic controls on abundance and distribution of the endangered Rio Grande silvery minnow in the Middle Rio Grande. USGS Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan.

Widmer, A.M., E.J. Gonzales, and L.L. Burckhardt. 2012. Fish community monitoring and sampling methodology evaluation. Comparison of methods used to sample the Middle Rio Grande fish community and the endangered Rio Grande silvery minnow – Final Project Results. U.S. Bureau of Reclamation and SWCA. Power Point presentation to Science Workgroup, August 12, 2012, Albuquerque, NM.

Winter, A. 2018. Fake minnows, probability, and fish statistics. Power Point presentation to Population Monitoring Workgroup, December 12, 2018. Bosque Ecosystem Monitoring Program, University of New Mexico, Albuquerque, NM.

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

Zipper, S.A., Hobbs, M.D., Hutson, A.M., and K.L. Lang. 2020a. Validation of daily increment deposition in larval Rio Grande Silvery Minnow otoliths. North American Journal of Fisheries Management. In Review.

Zipper, S.A. 2020b. Lapillar otoliths to determine daily age, growth rate, and estimated hatch dates from of wild captured larval Rio Grande silvery minnow *Hybognathus amarus*. Unpublished Manuscript.

Population Monitoring Workgroup Meeting

February 26, 2020
Albuquerque, New Mexico

Meeting Agenda

8:30– 8:45	Welcome, Introductions, Agenda Review, Meeting Notes ➢ Decision: Approval of February 26, 2020 meeting agenda ➢ Decision: Approval of November 6, 2019 PMWG meeting minutes	PMWG Co-chairs
8:45– 9:00	2020 Work Plan	PMWG Co-chairs
9:00– 10:00	Progress on Integrated Population Model	Charles Yackulic, USGS
10:00– 10:15	Break	
10:15– 12:00	Progress on Integrated Population Model (cont d)	Charles Yackulic, USGS
12:00– 1:30	Lunch (on own)	
1:30– 2:30	Consolidation of Science Panel Recommendations	Rich Valdez, Mike Marcus
2:30– 3:00	PMWG Report on Assimilation and Synthesis of Information and Data Stakeholder Questions for Modeling Effort	Rich Valdez Joel Lusk
3:00– 3:15	Break	
3:15– 3:30	Status of Data • Program Portal • Other data	Shay Howlin, PST
3:30– 3:45	Program Structure Planning • Functions and tasks of the PMWG • Discussion how those functions and tasks will fit under new Program structure	Facilitated discussion
3:45– 4:00	Wrap-Up • RGSM Habitat Suitability Modeling brown bag presentation in April (date TBD) • Action Items • Next Meeting	PMWG Co-chairs
4:00	Adjourn	

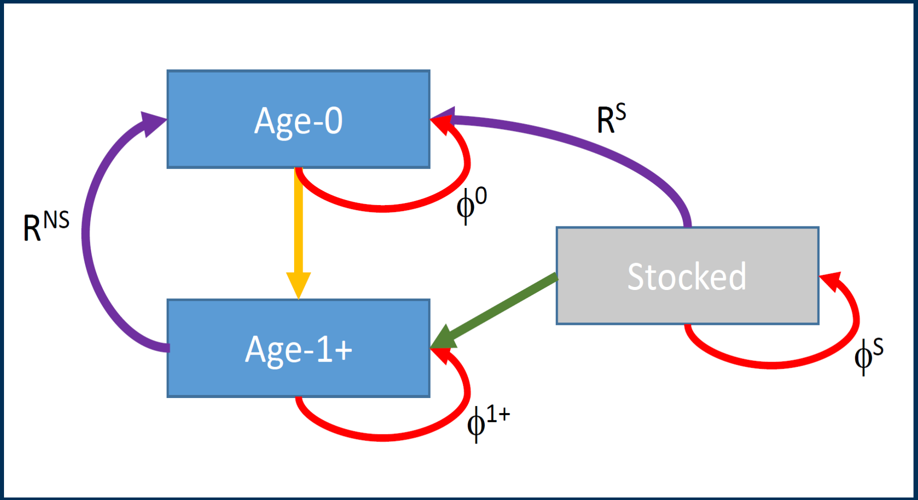
Highlights of PMWG

- July 13, 2012: EC Approved Charge for Task 1 (CPUE Workshop)
- May 2014: PMWG Sent a Survey to EC on Fish Population Monitoring Needs (Report in March 2015)
- Dec 8-10, 2015: Independent Science Panel Workshop on Population Monitoring (Hubert, Fabrizio, Hughes)
- April 13, 2016: Final Report on RGSM Population Monitoring (Hubert et al. 2016) (Task 1 Complete)
- July 12, 2016: PMWG forwards request to EC to Initiate Task 2 (Review Population Monitoring Plan)
- March 23, 2017: BOR incorporates Hubert Recommendations (8) into Pop Mon Contract
- June 2017: Final Report on RGSM Scientific Uncertainties (Noon et al. 2017; related to ACOE AM Project)
- Oct 4, 2017: PMWG Receives Additional Sites Protocol
- Oct 4, 2017: PMWG Decides to Develop an Integrated RGSM Model through Guest Biometrician
- Nov 29, 2017: PMWG Initiates Review/Prioritization of Hubert and Noon Recommendations
- Nov 29, 2017: PMWG Receives Replacement Sites Protocol
- Nov 11, 2018: Dr. Charles Yackulic Proposal for Integrated RGSM Population Model
- Oct 2019: Questionnaire Sent to PMWG Stakeholders on Possible Uses of Integrated RGSM Model

Rio Grande Silvery Minnow integrated population model

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

email: cyackulic@usgs.gov



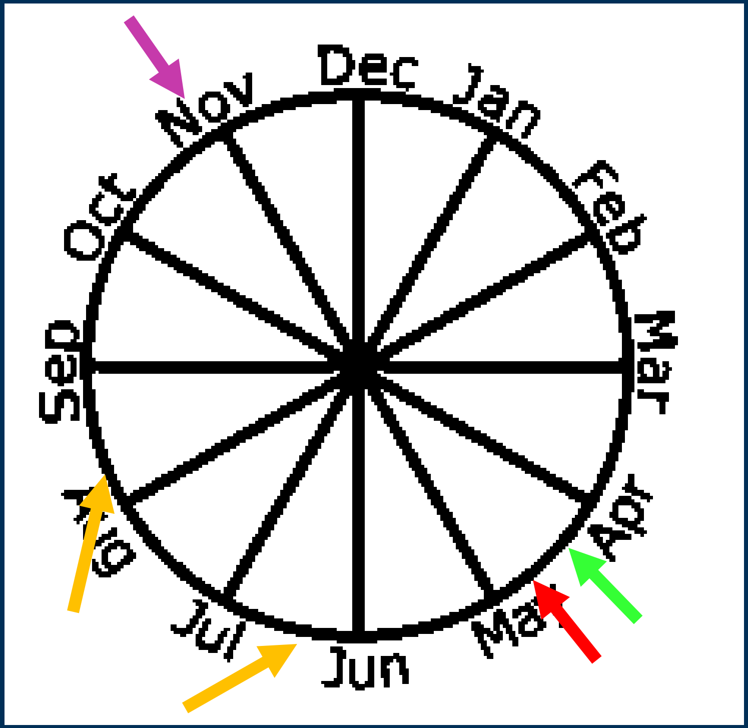
U.S. Department of the Interior
U.S. Geological Survey

Outline

- Refresher on assumptions & past progress
- Spatial scale – challenges and solutions
- Final (ish) model structure
- Model output
- Next steps

USGS

Timing of life history and other key events



Spring runoff, floodplain inundation

Spawning

Peak irrigation, drying, salvage.

Augmentation

Questions/assumptions

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

USGS

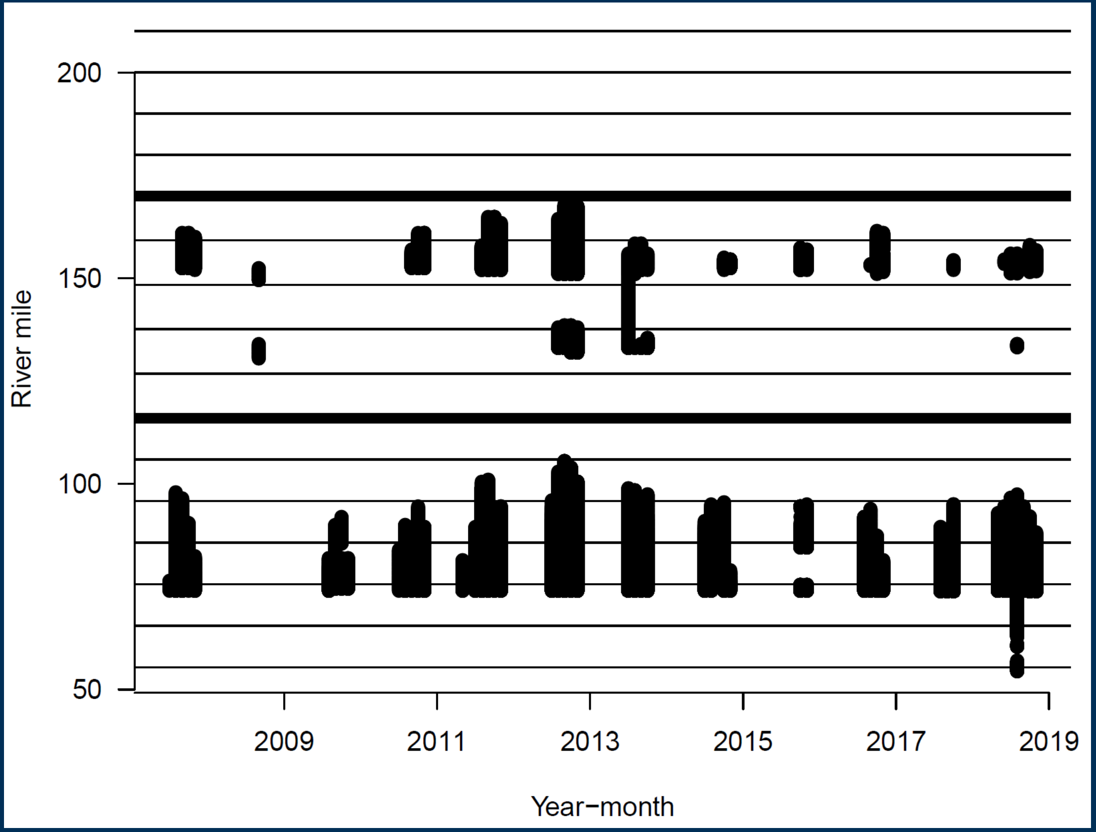
Data

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

USGS

Other data

- Salvage
- Repeat surveys
- Drying data



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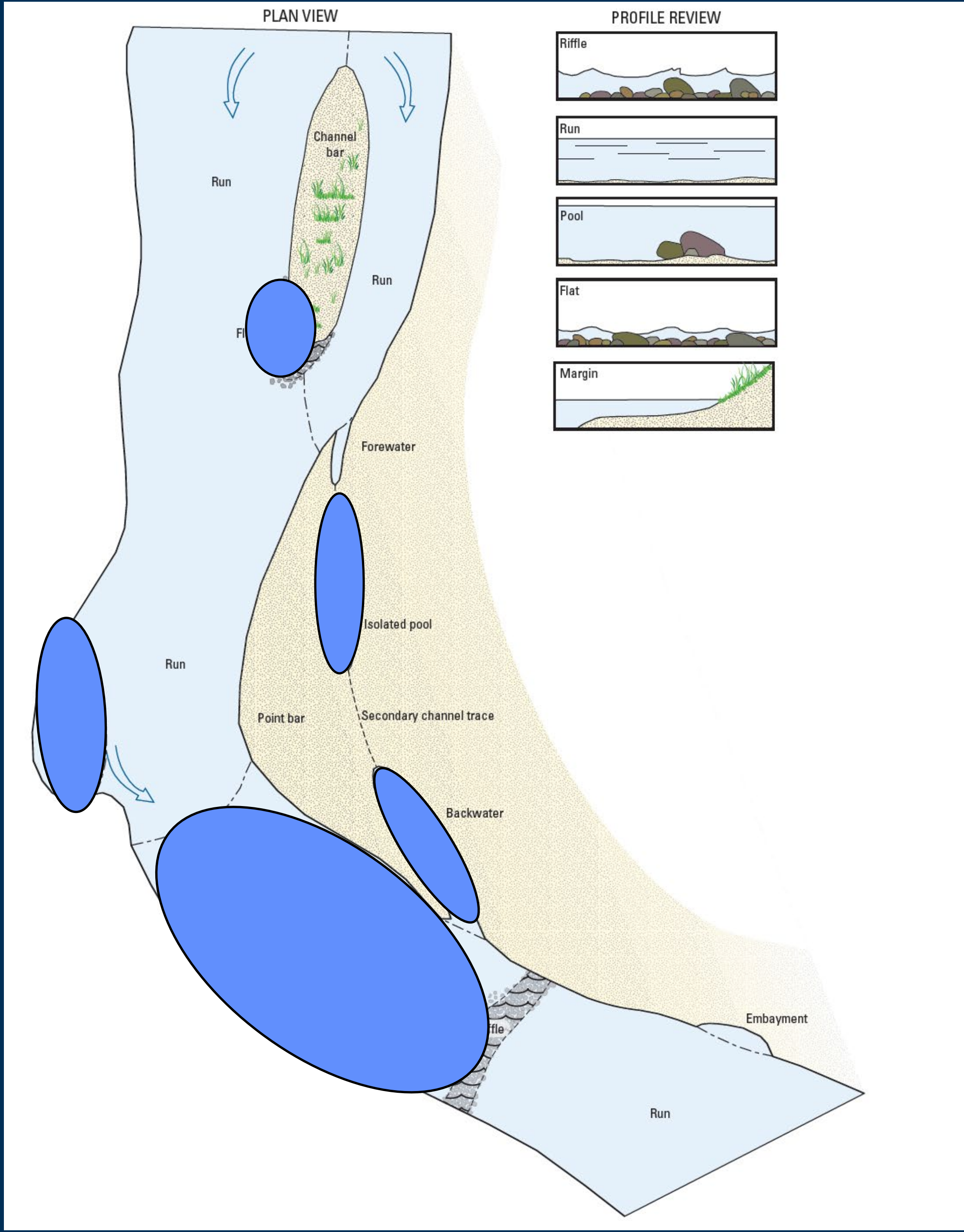
Mesohabitat

- Pool
  - ~4x catch rate of age-0
- ~25% of samples taken in pool type habitats



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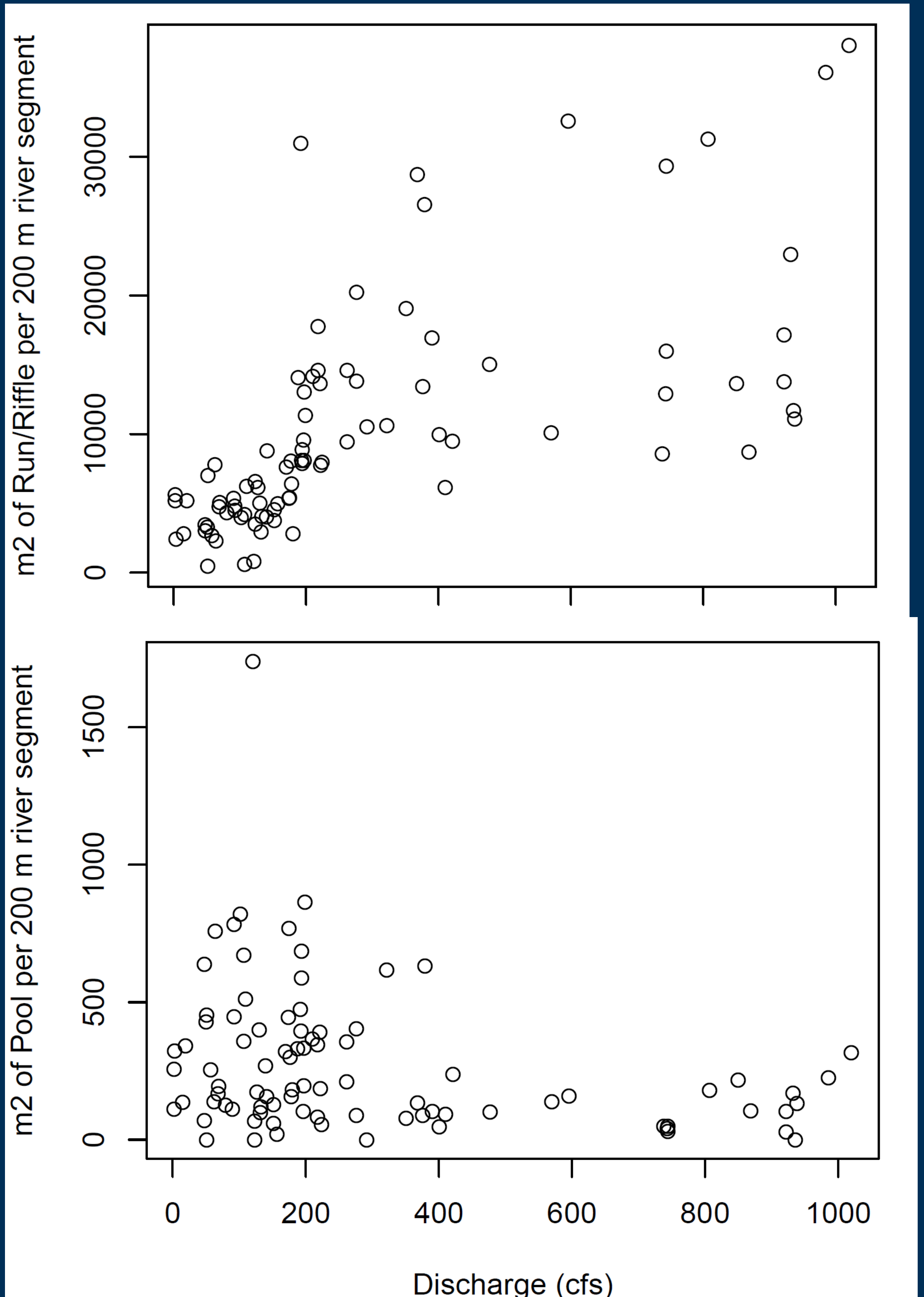
Strata area

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



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Spatial questions

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

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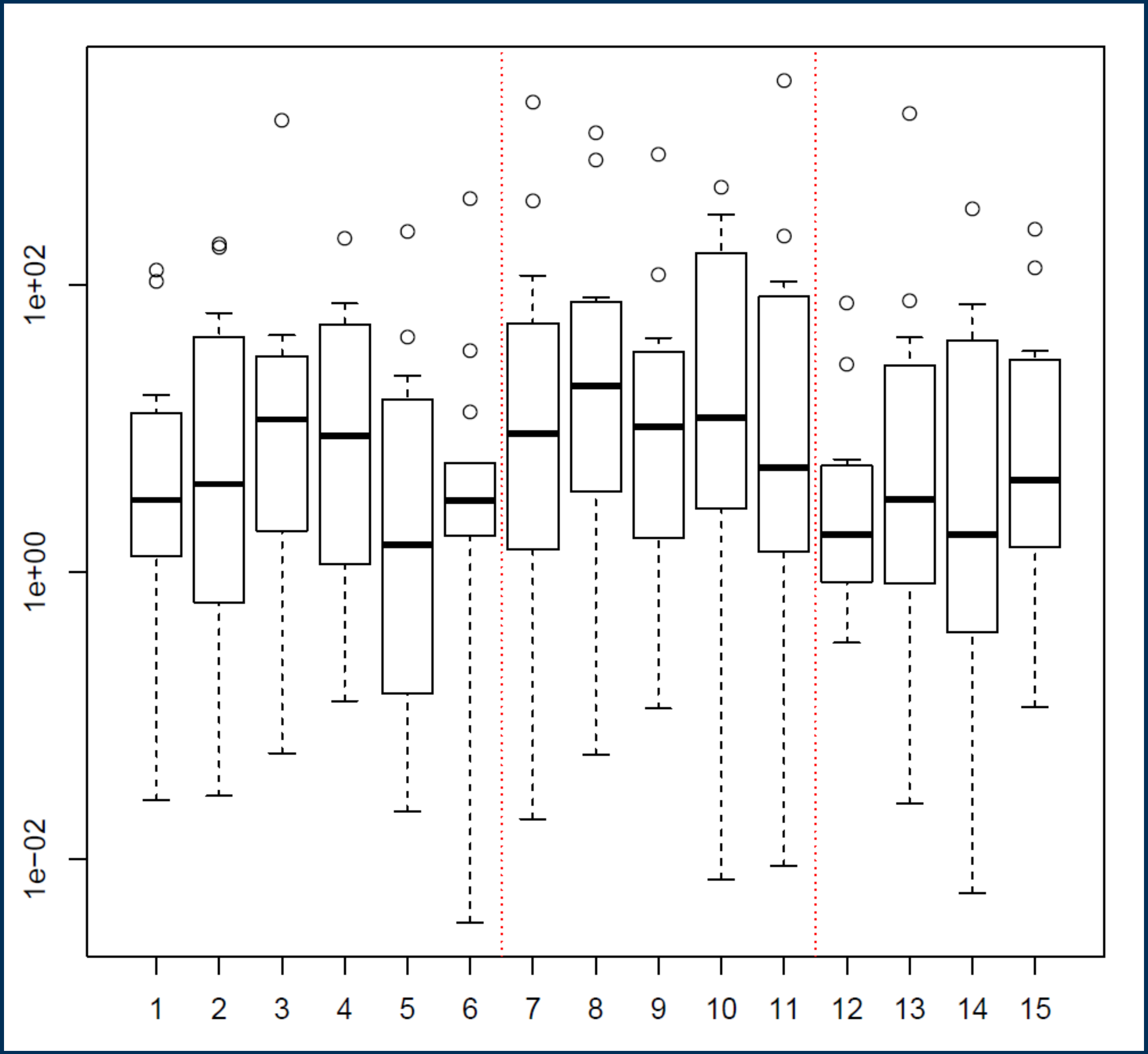

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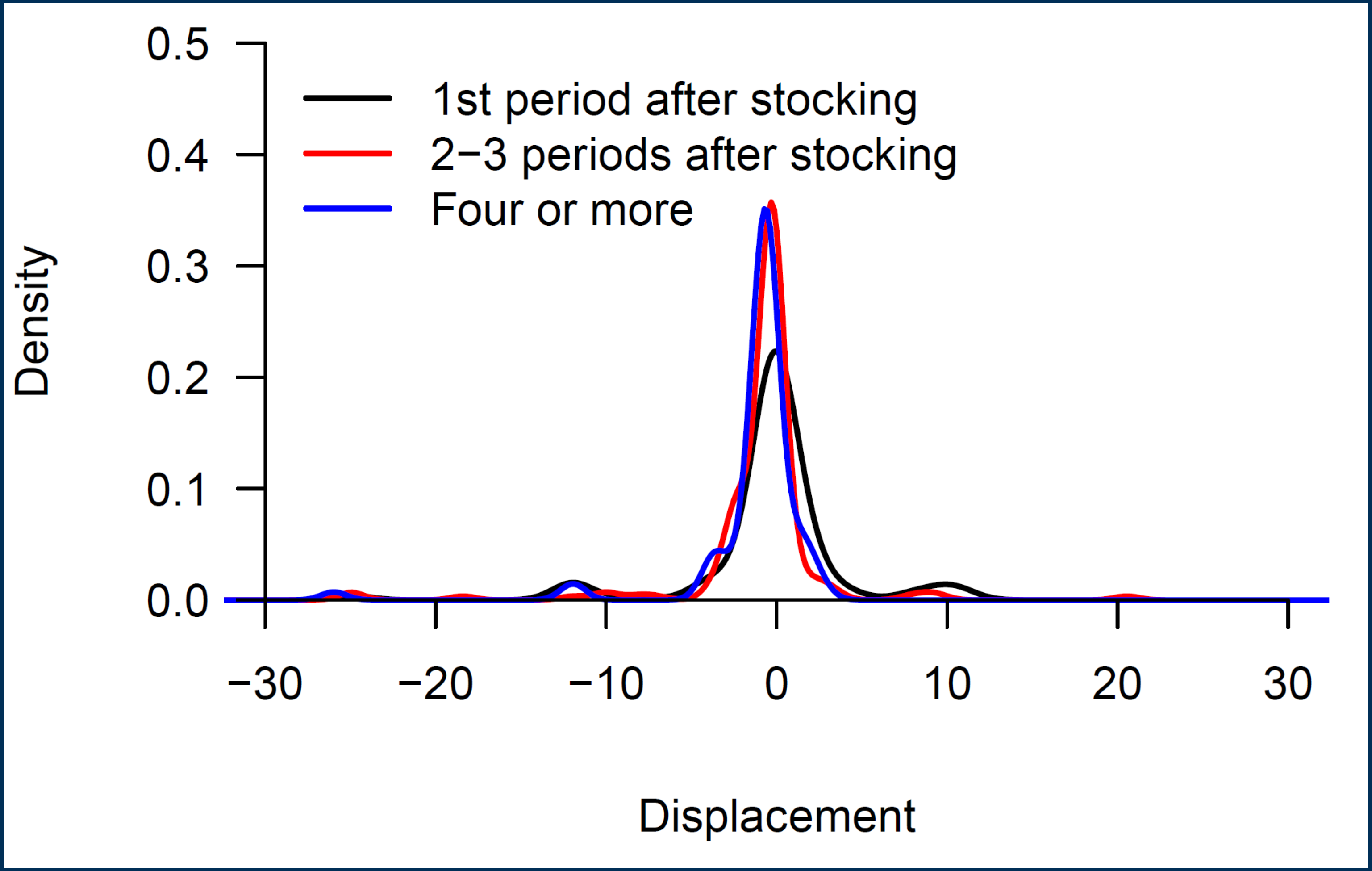

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Conclusion

- Not enough signal in these data to get at these spatial questions.
- Could revisit down the line if other data sources become available.
- Ended up taking very coarse approach (3 reaches)

USGS

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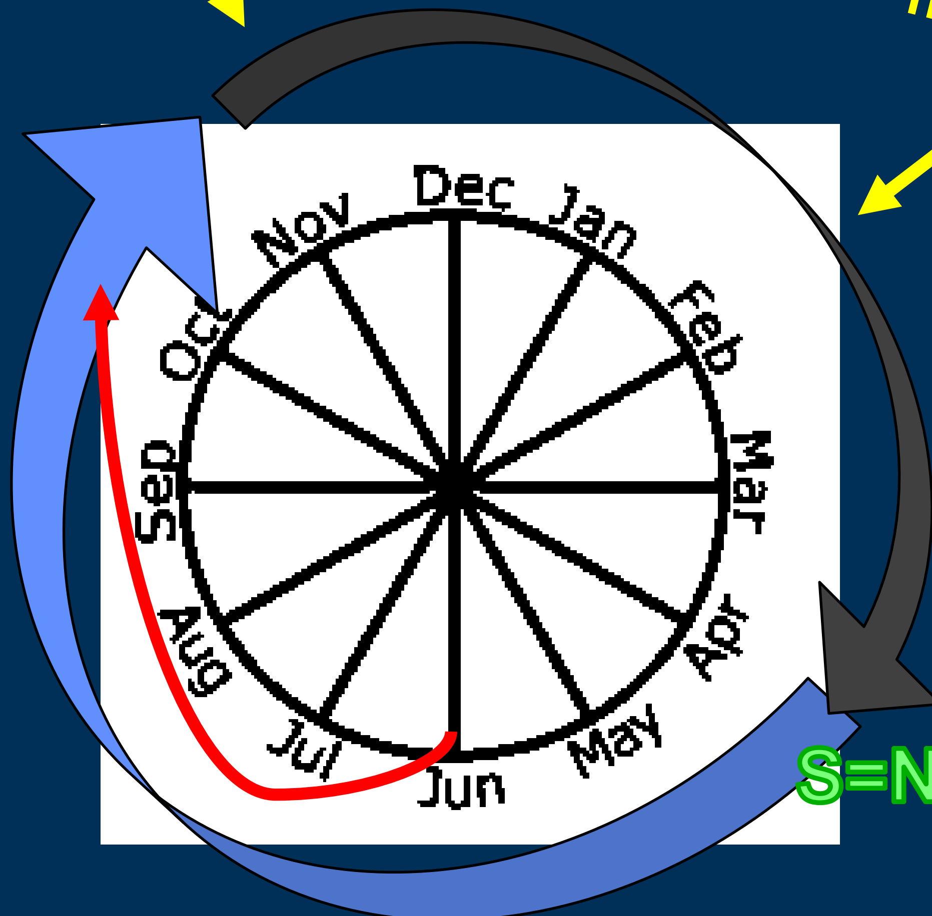
USGS

Most stocking here or here – initial mortality

Monthly survival different until October



Survival assumed constant over “winter”

$$S = N_{adults} + b * N_{stock}$$

$$R = aS/(1 + aS/R_f)$$

Rf – carrying capacity – function of flow/inundation

Underlying structure

- Project N over months in different categories (yoy, adult, and stocked) and different reaches (Angostura, Isleta, San Acacia)
- Catch (and effort) summarized by coarse habitat type and gear in each month for each category/reach.
- Predictions of catch (or N) compared between model and data

Details

- The amount of river that RGSM live in varies substantially, as does the proportion of run/riffle and pool habitat.
  - α – density in pools relative to run/riffle
  - Different for yoy and adult
- Model pool and run/riffle availability relative to discharge.

USGS

Details (continued)

- $N/(A_{rr}+\alpha A_p)$ – expected density in run/riffle
- $\alpha N/(A_{rr}+\alpha A_p)$ – expected density in pools
- Predicted catch = Density * p * area seined
- Use negative binomial to compare data to predicted catch

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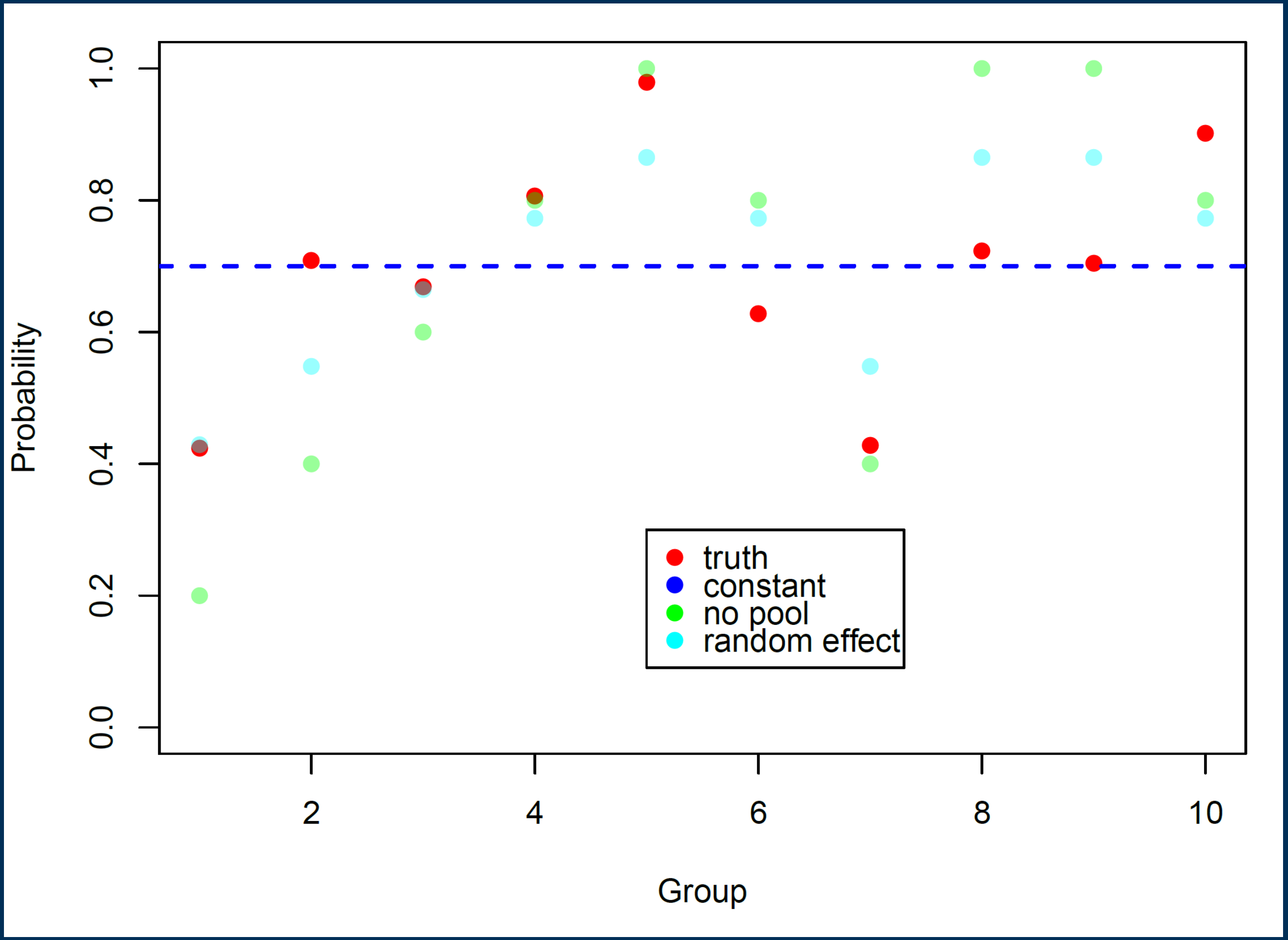
Random effects and pooling

- **Good option with sparse data.**
- **Can hide pattern if there insufficient statistical power.**



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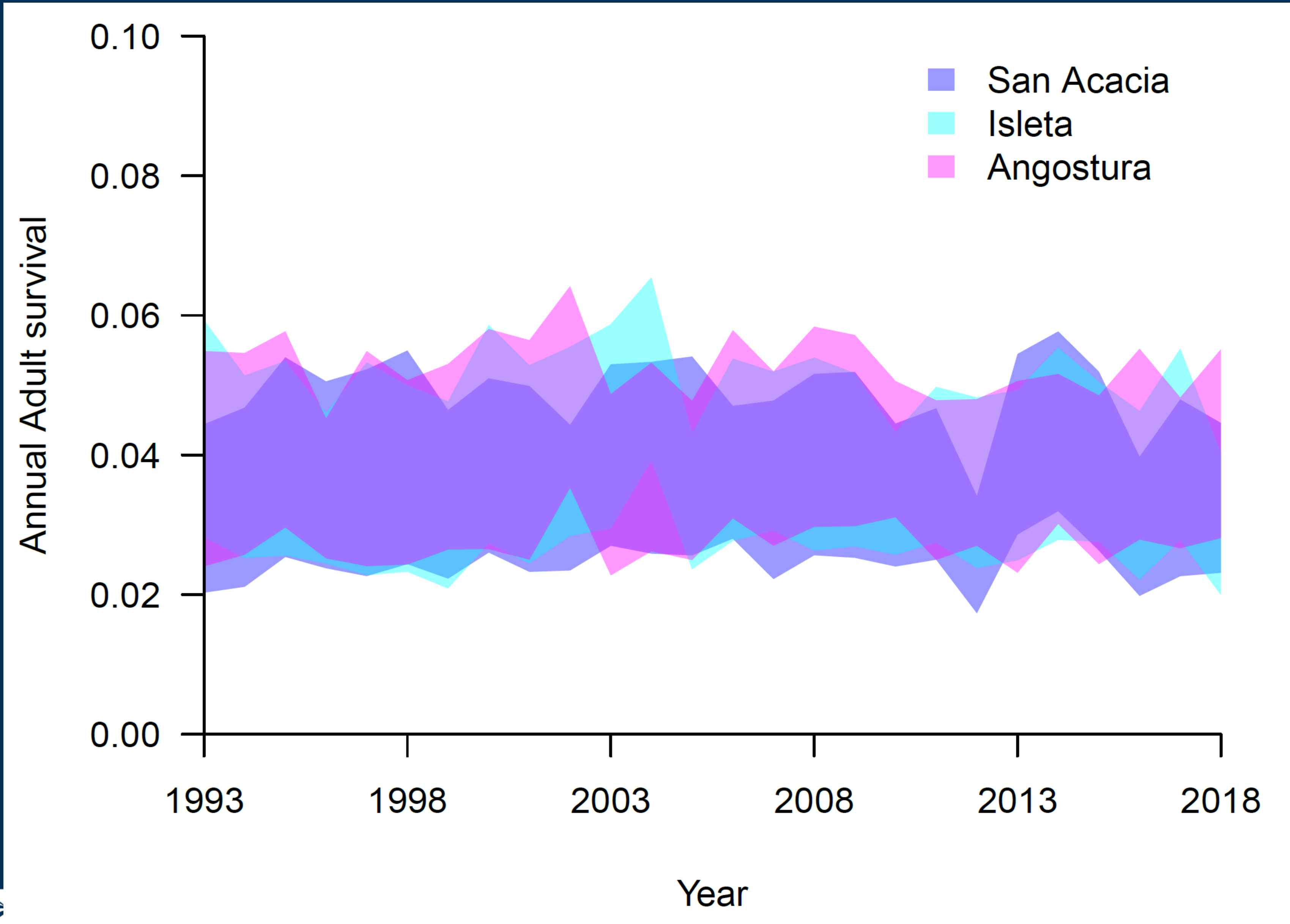

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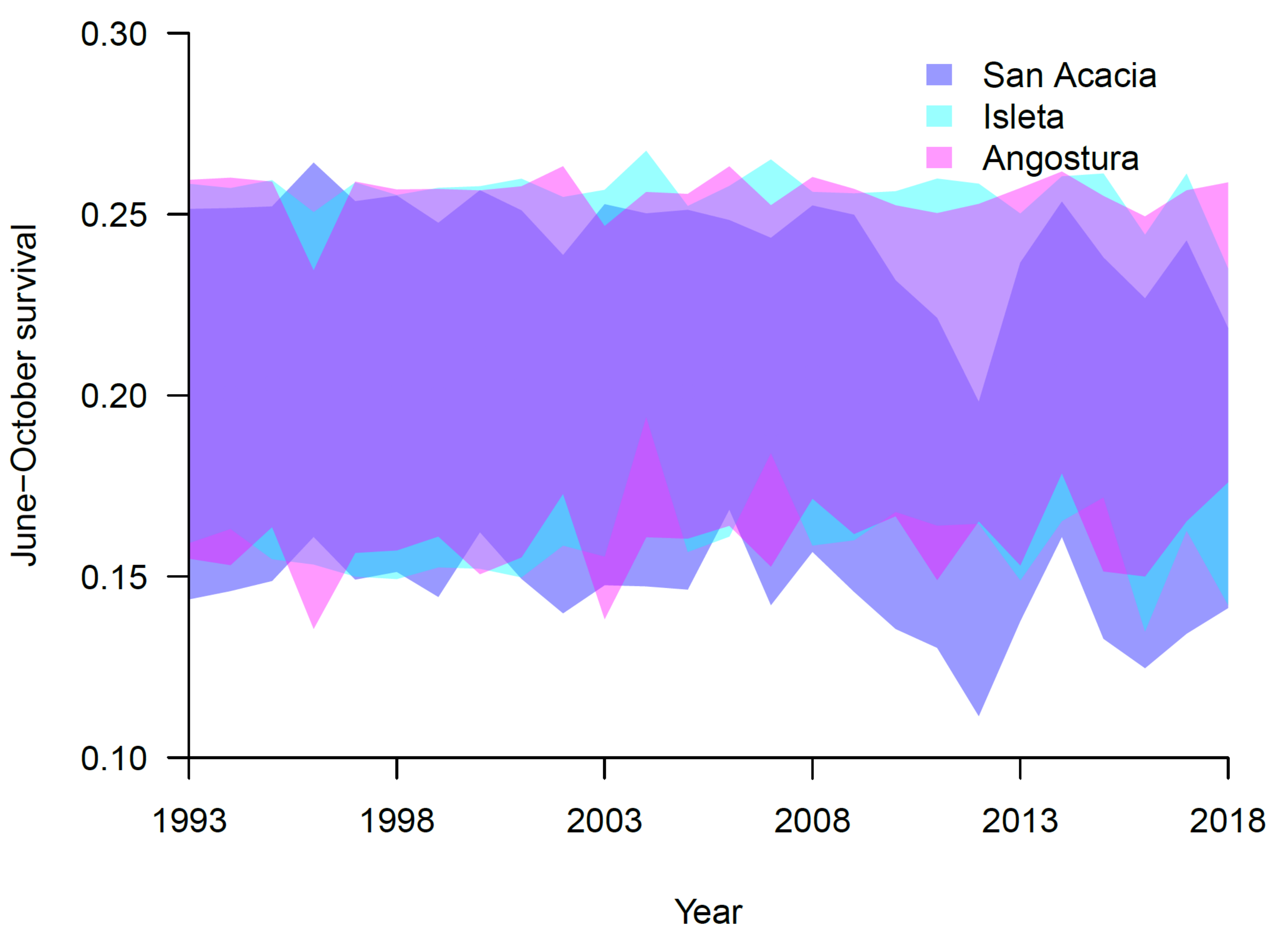

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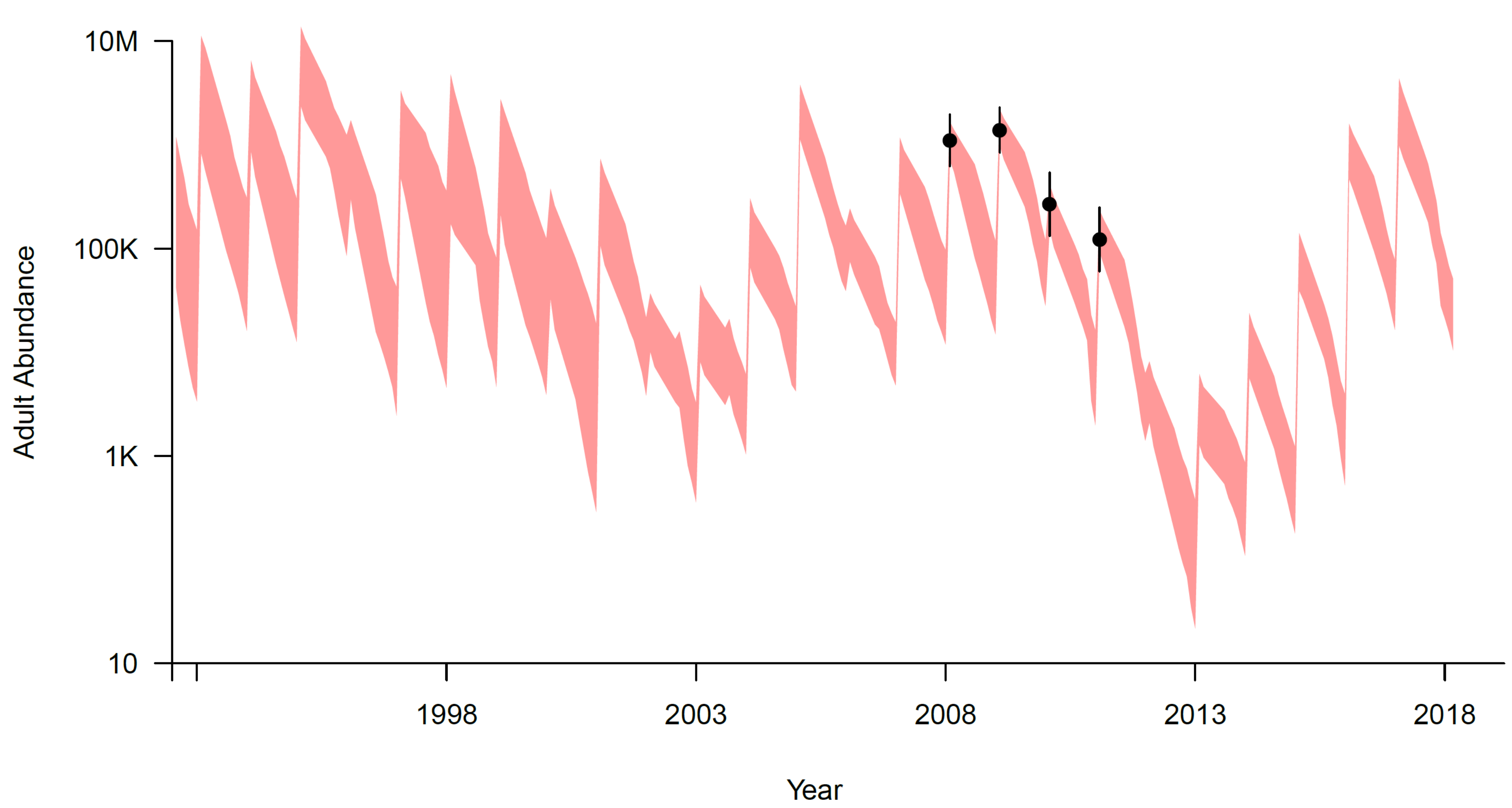
Black dots and standard errors are from population estimation program and are used as data in the model..increase each year occurs in October when age 0 are added to age 1+ population. Height of bars corresponds to 95% CI.



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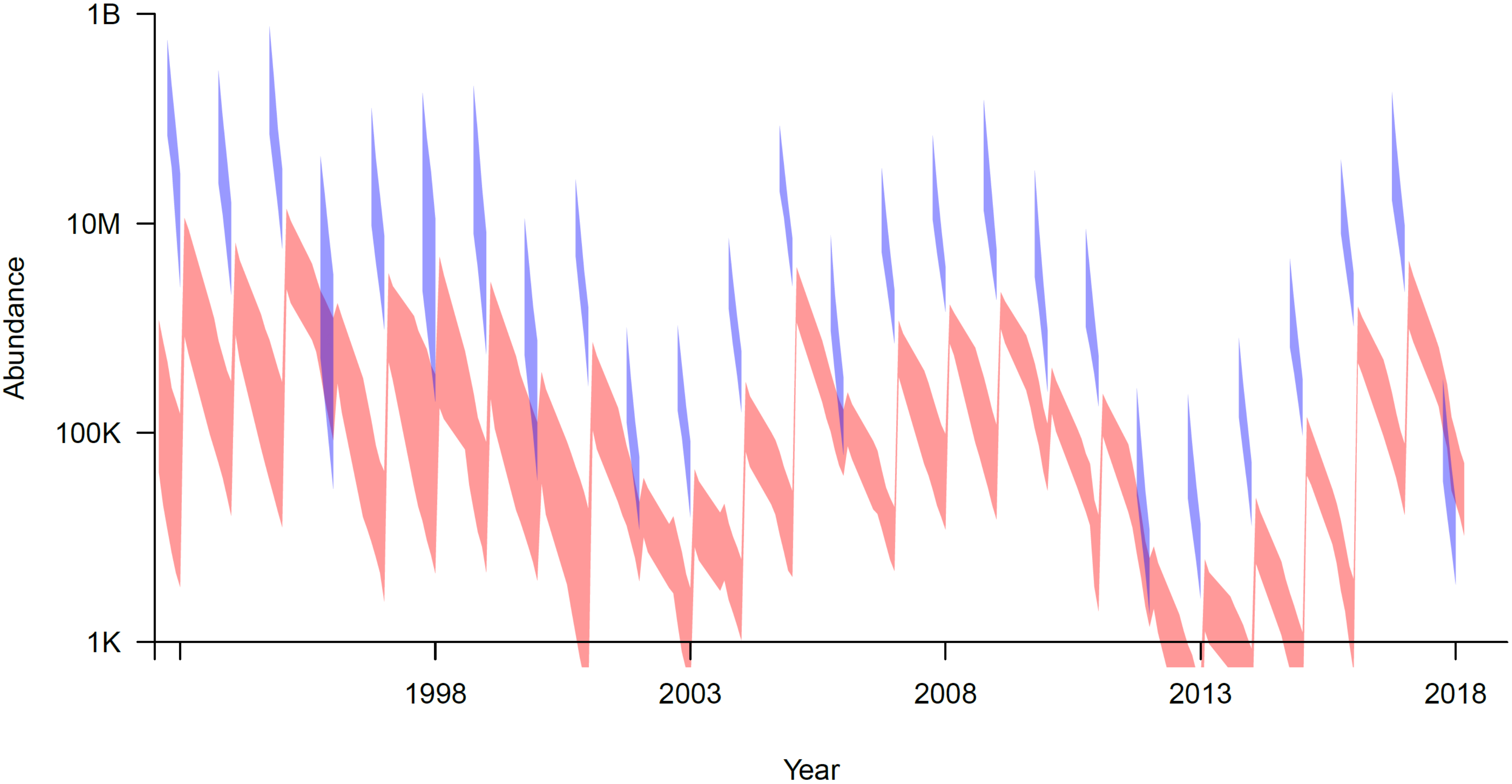
Red is same as last slide (age 1+), Blue are Age-0. Age-0 are only estimated from April to Sept and then transition to Age-1+.



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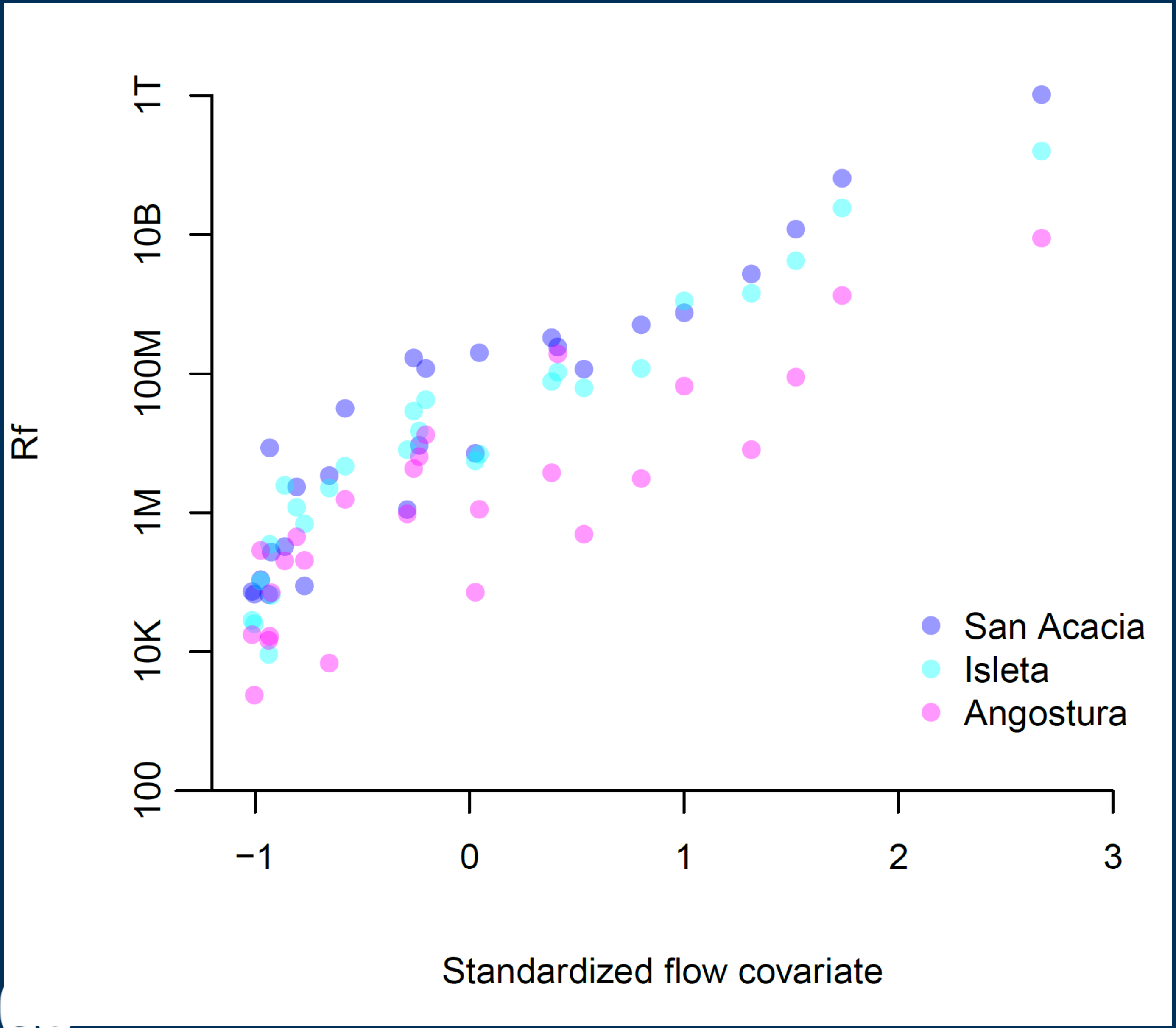
Rf is the reach and year specific carrying capacity.



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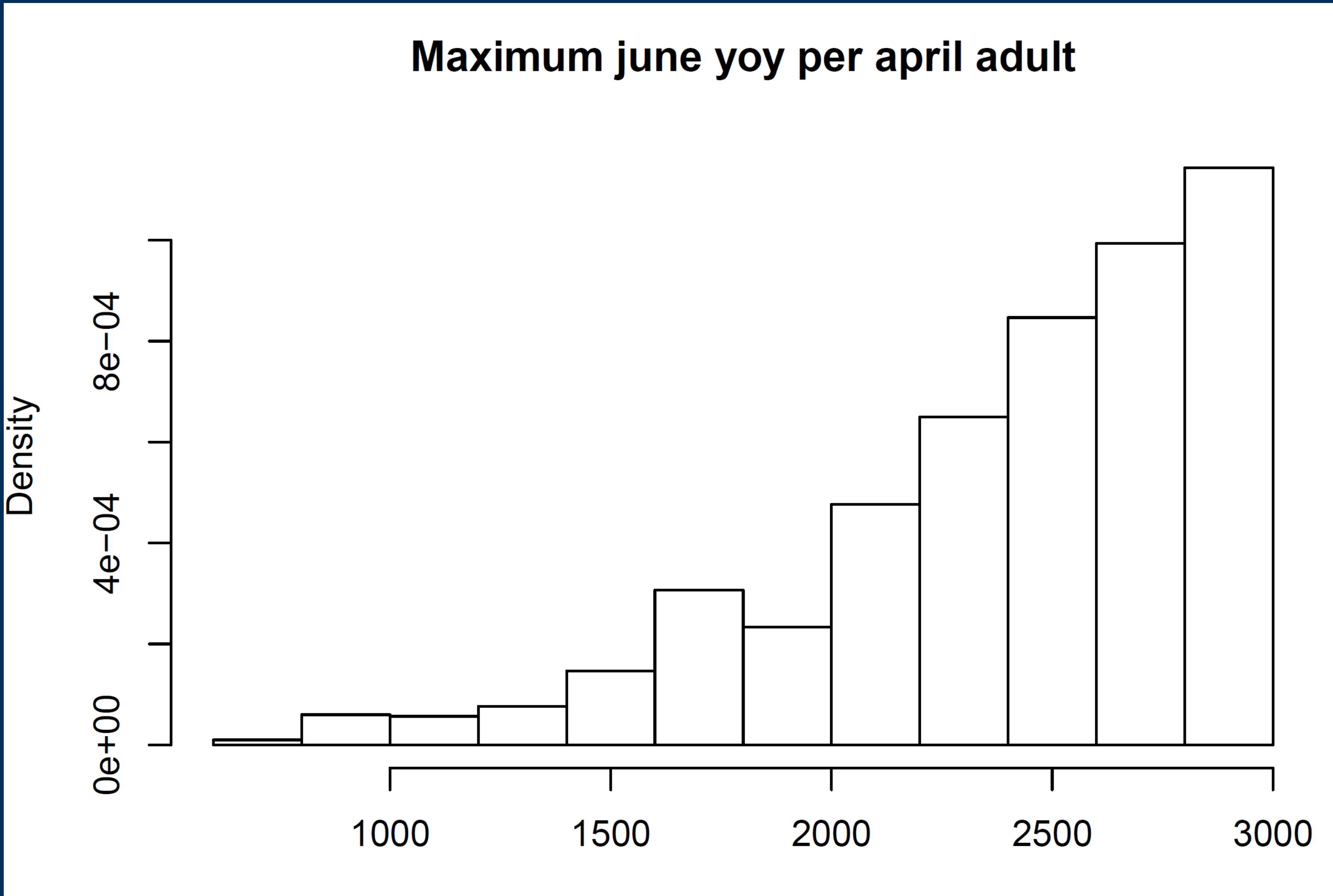

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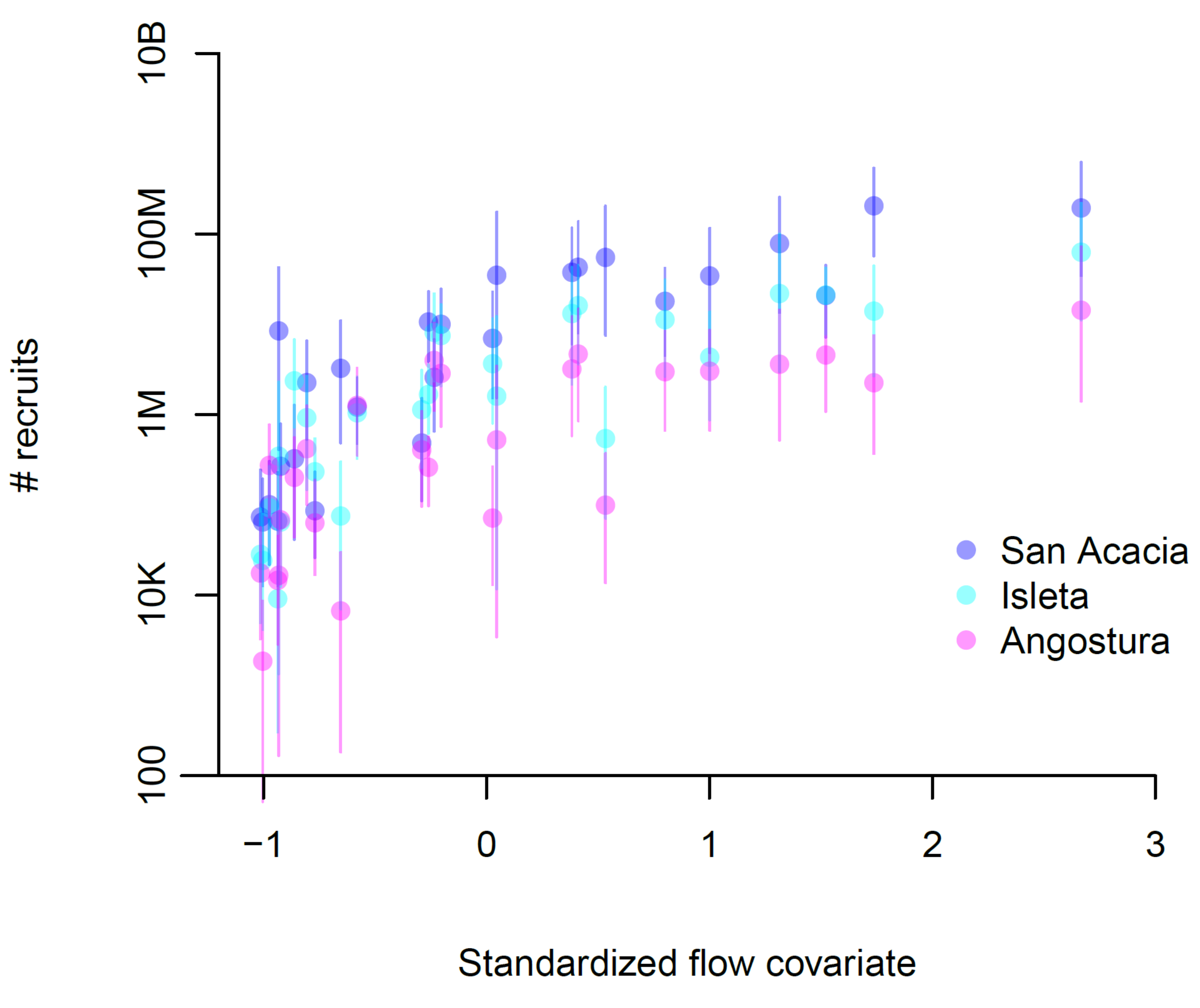

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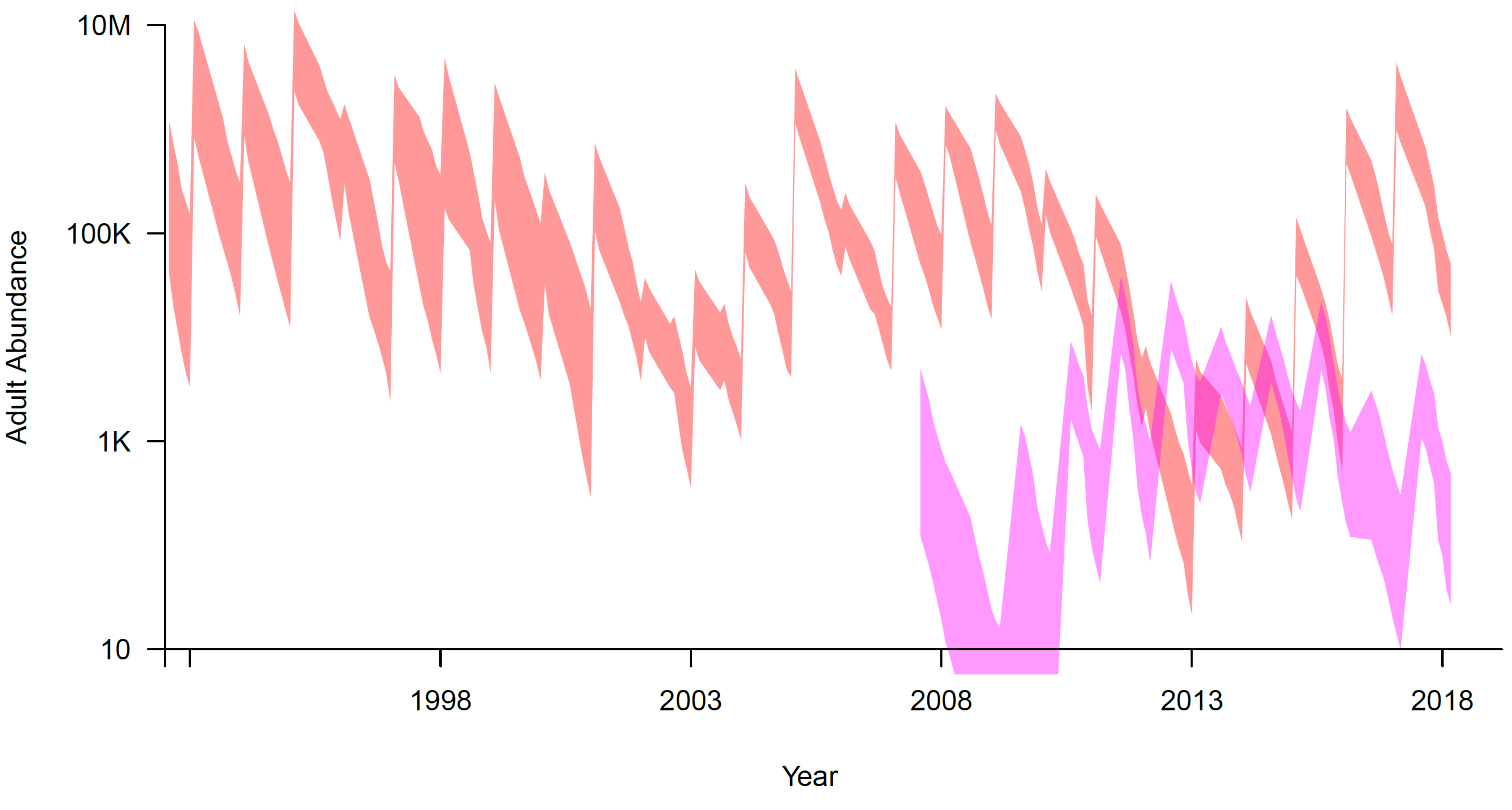
Pink is the number of stocked fish in the system (only added to model after they survive an interval so most stocked fish have to survive initial stocking mortality and overwinter mortality.



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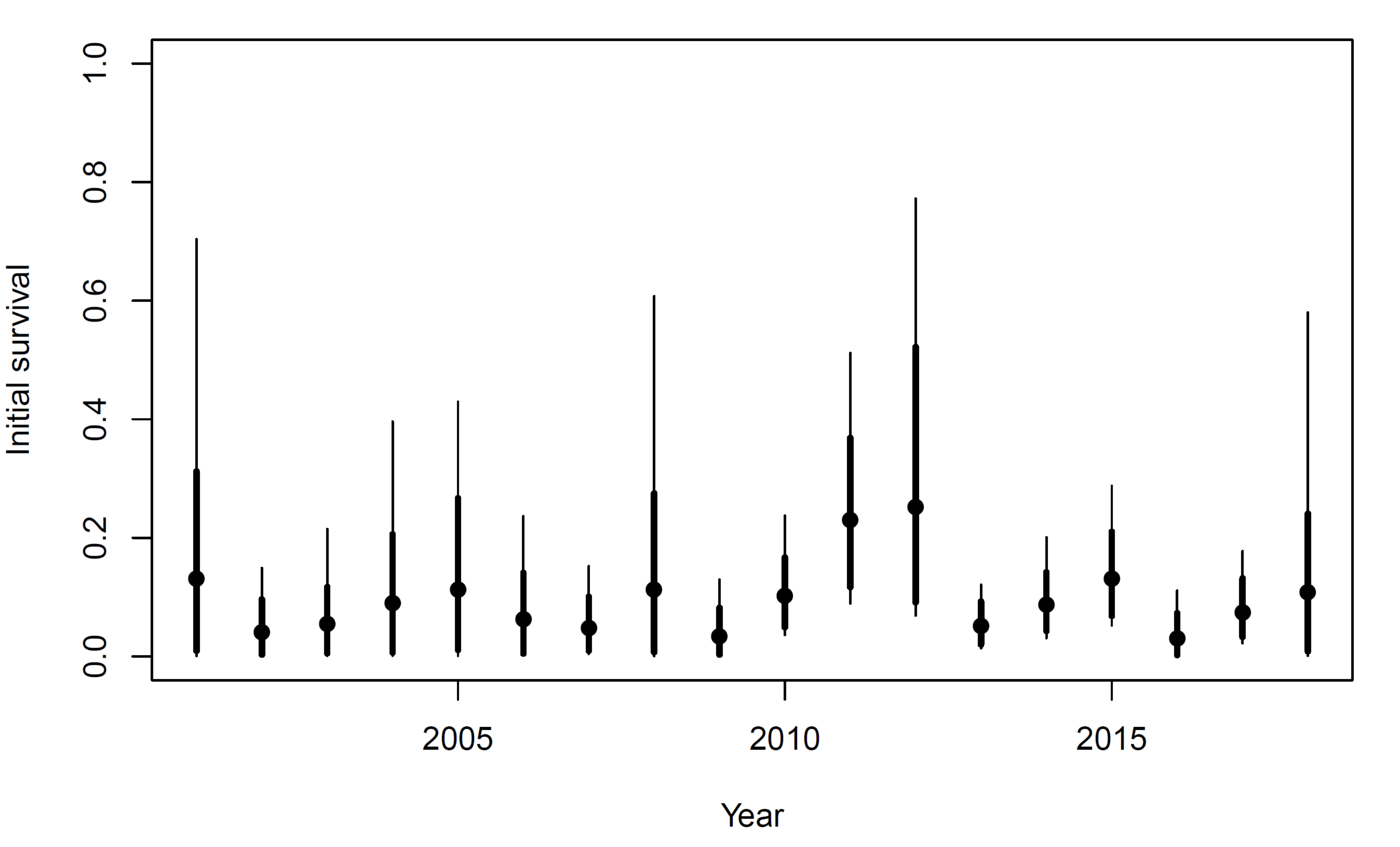
Initial stocking survival (potentially sensitive to spatial information and worthy of additional analysis).



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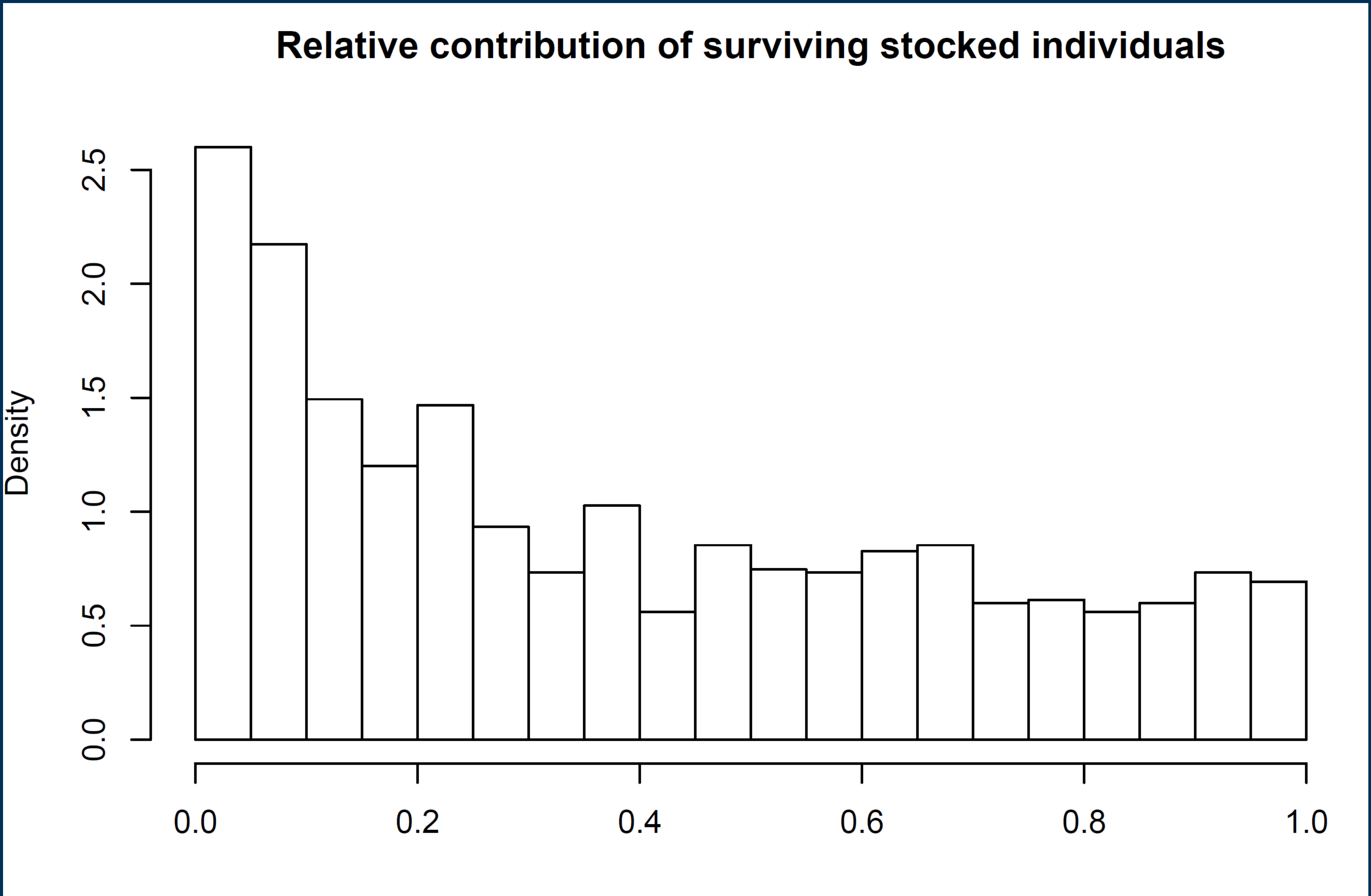

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Outline

- Refresher on assumptions & past progress
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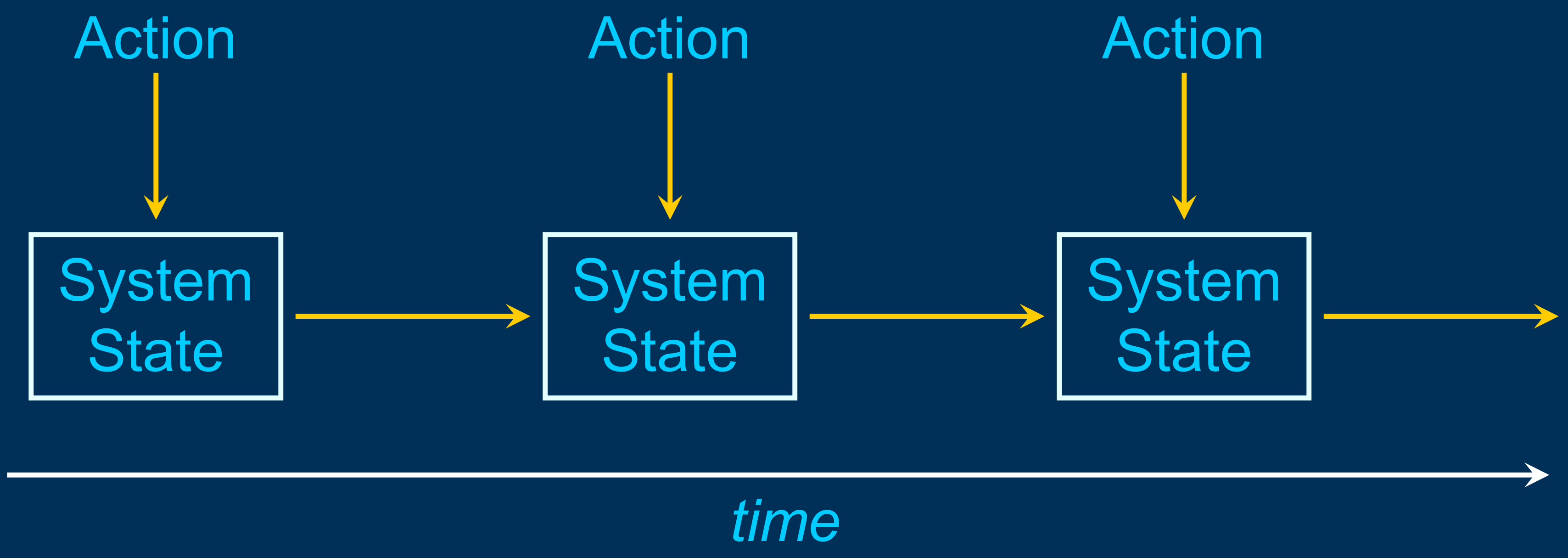
USGS

Next steps

- Could improve habitat modelling – not using all the information.
- Could also improve analysis of stocked fish.
- At same time, don't want to wait for a "perfect model."
- "All models are wrong, some are useful" – Box

USGS

Science needs to improve predictions to be useful.
Process understanding (arrows)
State-dependent decisions (boxes)*



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Prediction, models and management

- Very few ecological questions are definitely answered with single studies.
  - Biomedical studies –75-90% of published, preclinical results can be reproduced
  - Even worse when a single study with replication equal to 1 or 2
- But statistical significance shouldn't be basis for management decisions (Trends)

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A working example of Adaptive management: Mid-Continent Mallard Harvest

- Initiated 1995
- 4 distinct hypotheses
- Abundance estimated by aerial survey
- Model weights updated: comparison of estimate with predictions

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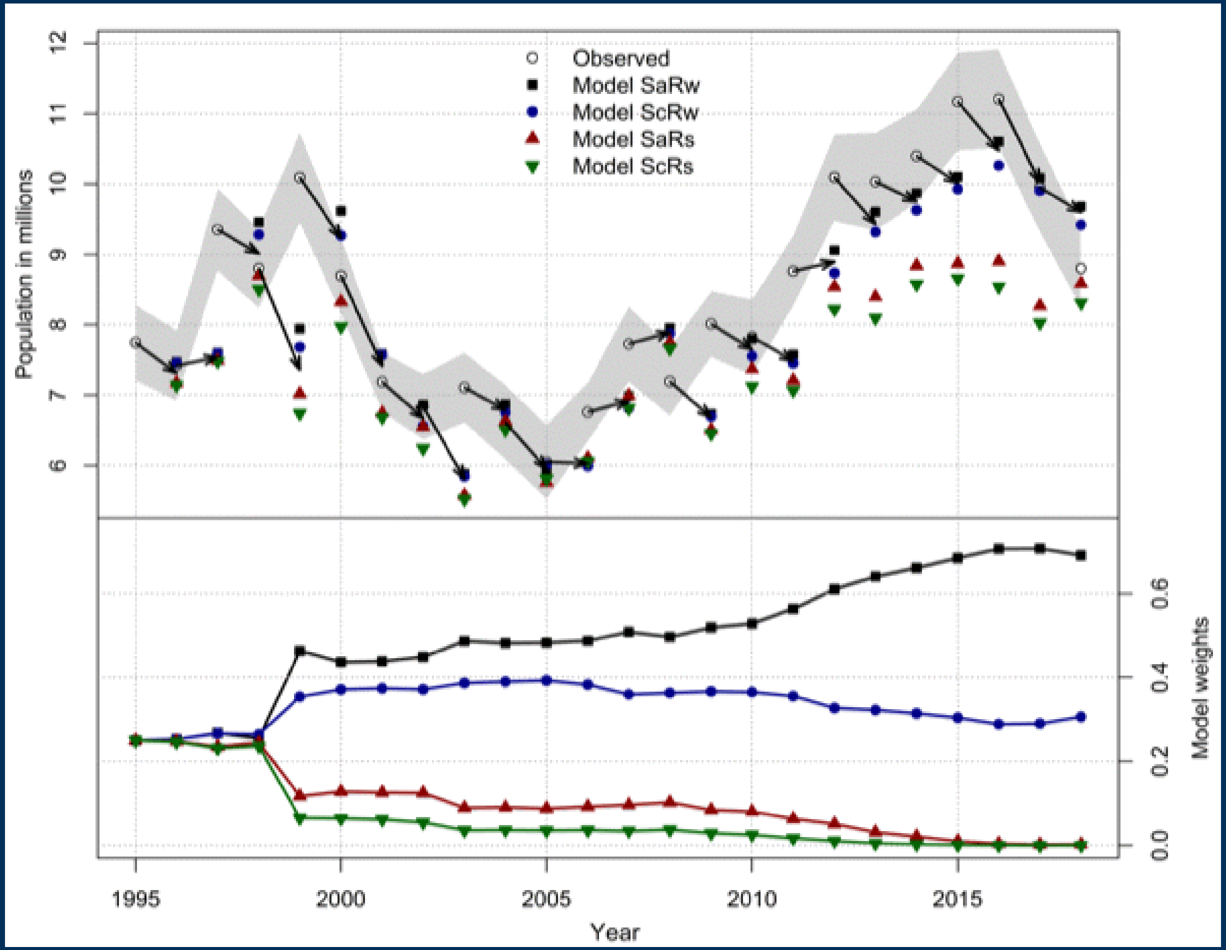
Mid-Continental Mallard Harvest has been informed by 4 models for over 20 years with model weights updated over time to reflect learning from data



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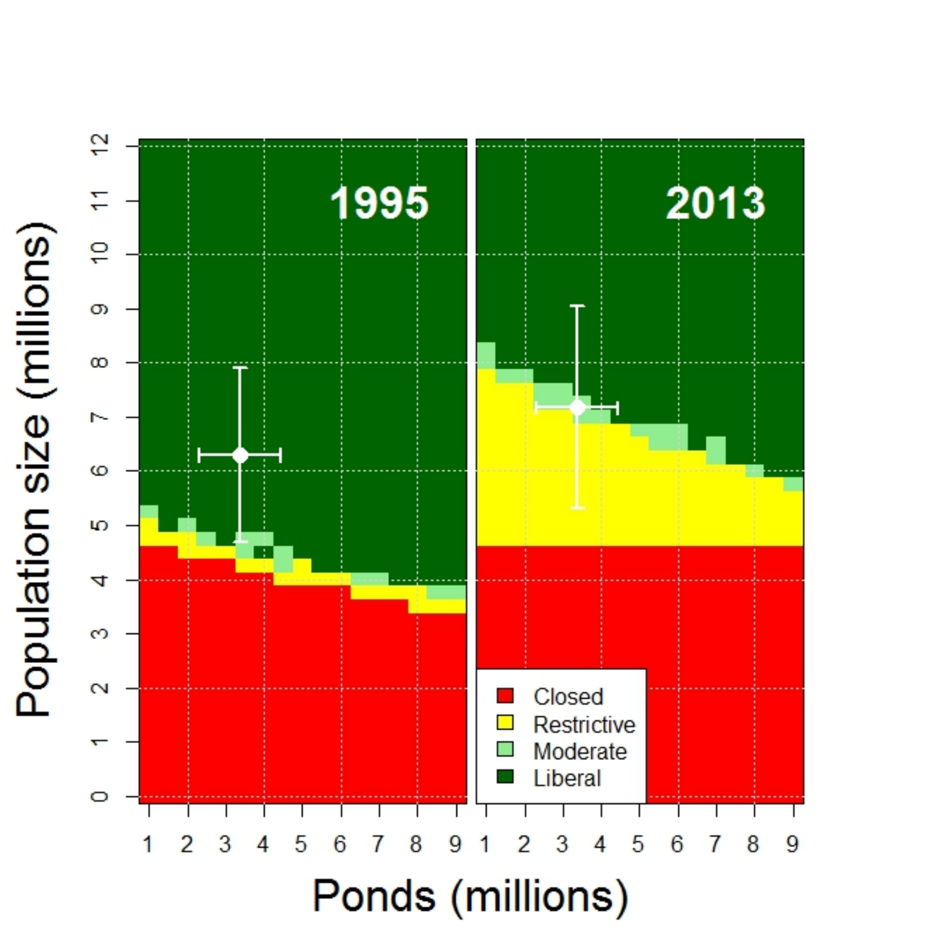
Nichols et al., 2019

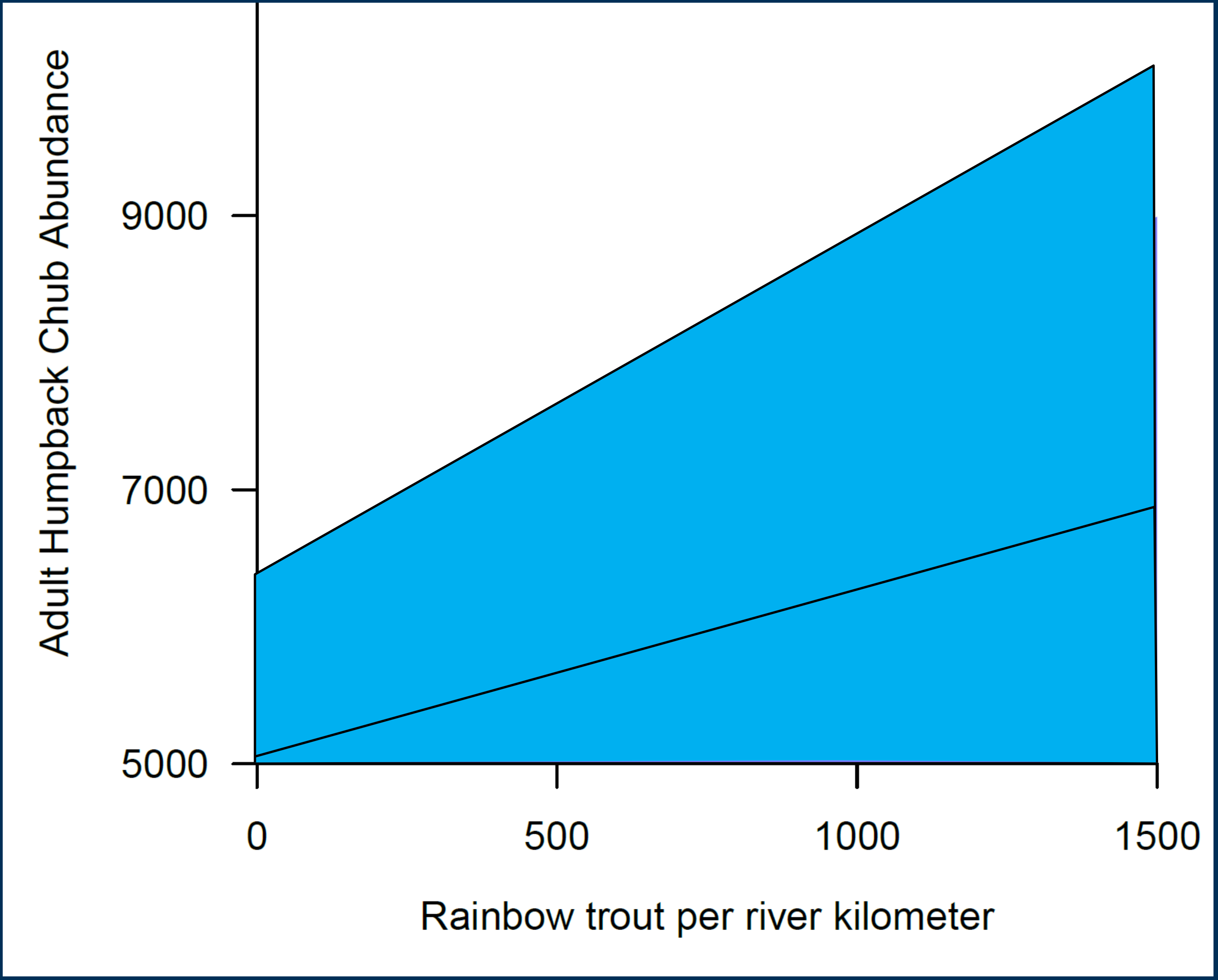
Harvest policy has been updated adaptively with differences in model weights



USGS

Nichols et al., 2019

We have been working to develop similar approaches for updating decision rules with monitoring results



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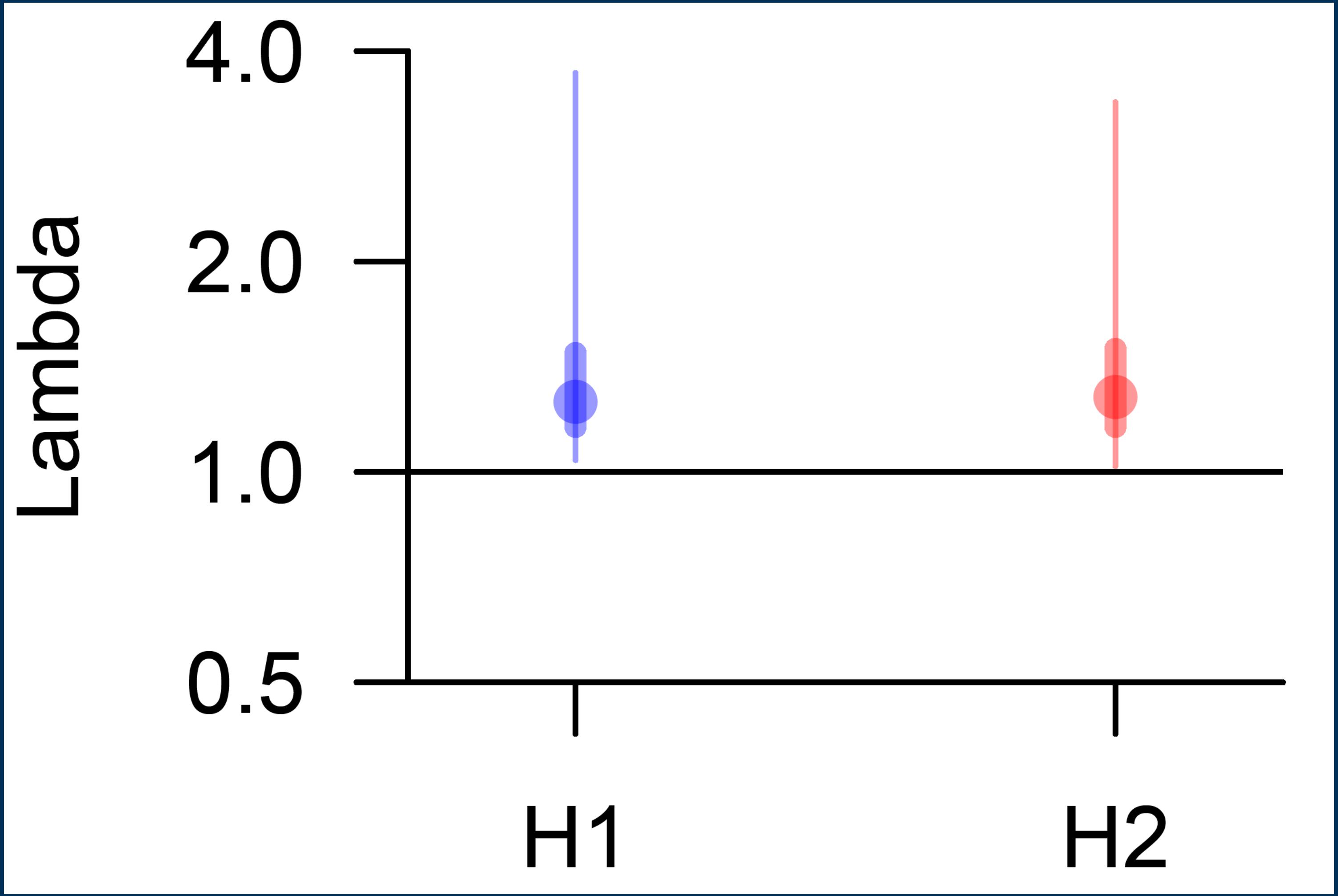
Adapted from Donovan et al., 2019; Yackulic et al., 2019

There is no doubt population growth will continue if things don't change



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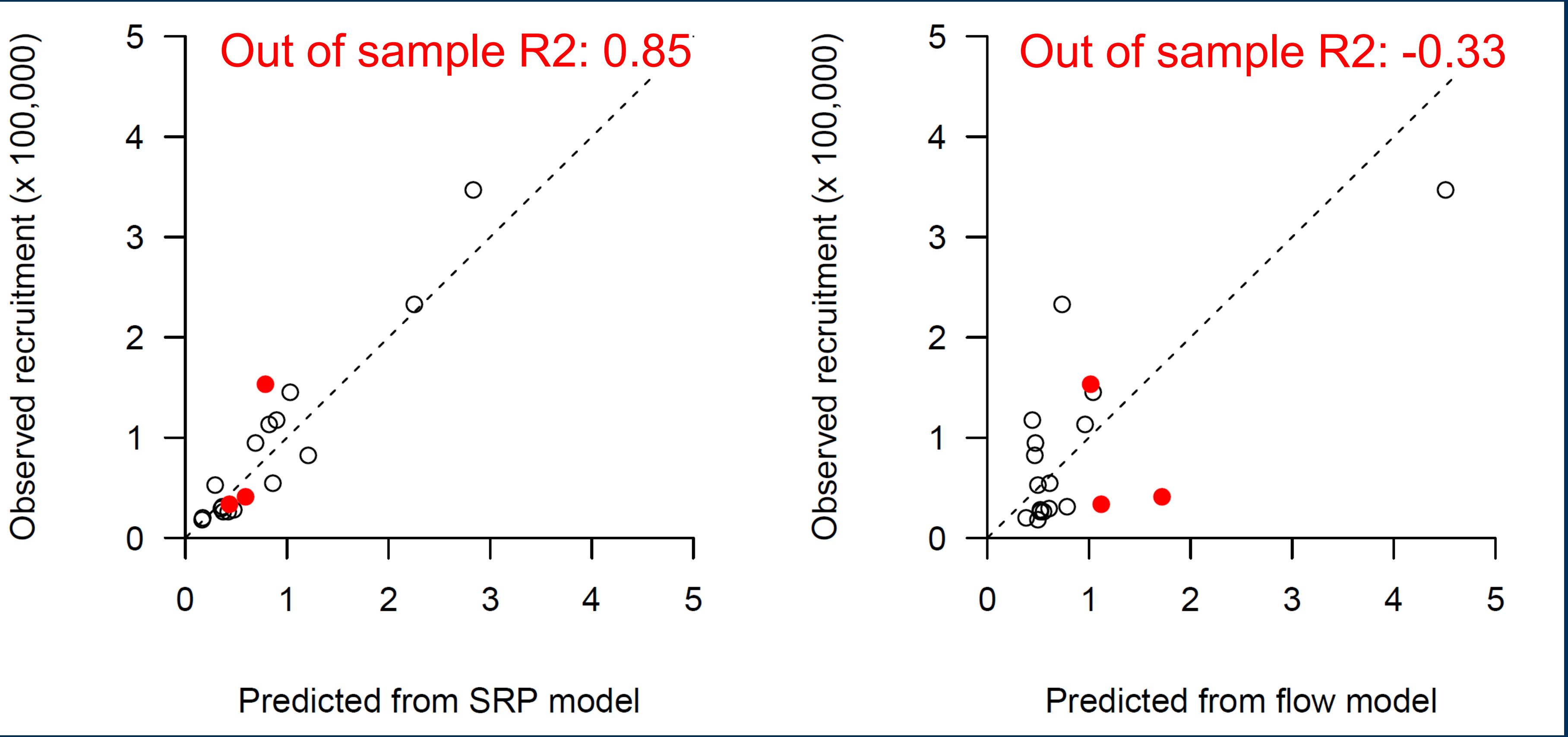
Preliminary data, do not cite

Rainbow trout recruitment models fit for 2017 annual reporting meeting



Model using SRP and existing rainbow trout population size as covariates previously outperformed model used in LTEMP EIS.

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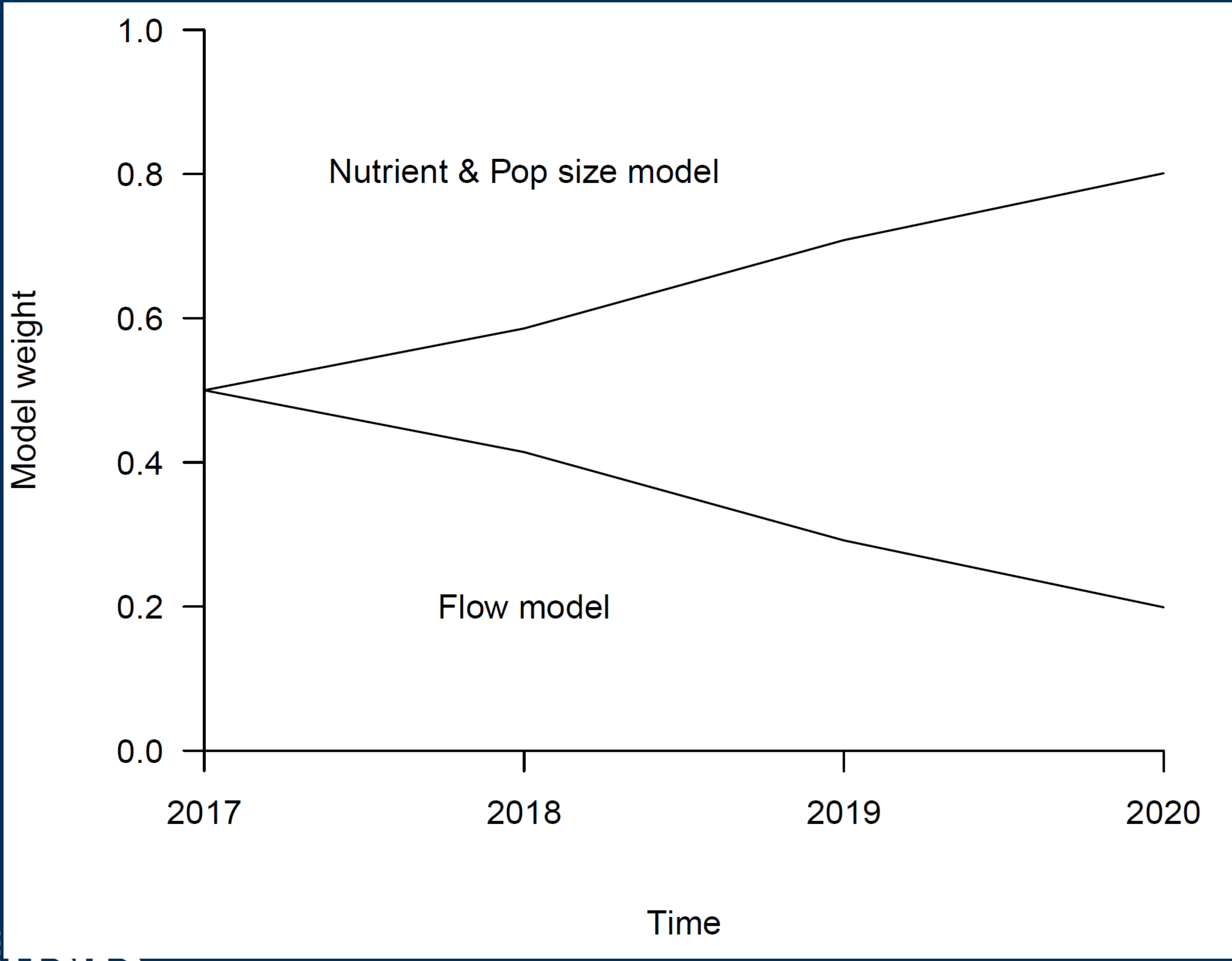
Preliminary data, do not cite



Preliminary data, do not cite

Summary Table of Stakeholder Responses to Questions about the Integrated RGSM Model.
Compiled February 21, 2020 by Joel Lusk

Category->	Use Model to evaluate water management actions (spring mgt options, vs drying, costs)	Use Model to answer pop parameters, dynamics or recovery	Use Model to evaluate reach metapops	Use Model to quantify various effects to population or individuals	Use Model for evaluating augmentation or salvage activities	Use Model for evaluating habitat or habitat restoration	Use Model to evaluate CPUE confidence or other reliability
	11	8	2	4	4	7	2

The PMWG sent a survey to the MRGESCP stakeholders in October 2019 to elicit the more important questions of the model that stakeholders would like to see addressed. The following are responses to this survey, without attribution as to the identity of the stakeholder:

Example Questions from Survey:

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

Responses:

1. The questions in #2 above are the questions that I would like considered.
2. What does a self-sustaining population of silvery minnows look like in the Middle Rio Grande according to this population model?
3. Agree with above questions; also consider modeling response of salvage and augmentation management actions (inputs and removals from population).
4. For spawning: Is flowrate the important parameter, or is it really the amount of overbank flow? How do we balance flowrate with duration of peak flow, given that in years when the peak must be actively managed, water volume is limited? If water is very limited (as in 2018), what is the best balance to be struck between river continuity (i.e., drying) and some sort of pulse flow? general: Given that we have seen extremely high densities following years with zero or very low October densities, how much confidence do we have in the way we monitor and measure minnow density? And how low can density go and the minnow be able to recover? What are the impacts of things we have little to no control over, like water quality?
5. I have questions about the efficacy of river connectivity during the irrigation season, which is often maintained using very low flows, e.g., a few cfs due to pumping at the BDA south boundary pump channel. (1) Are these low flows supportive of minnow survival and, if so, how is that measured? (2) Is there an alternative to "low flow

connectivity" that would make better use of these small amounts of water for species survival?

6. Does fish rescue during summer affect the population in October?

   How does the model handle meta-populations in the existing reaches and future experimental populations?

   Does the model evaluate the reproductive contributions of the various age-classes?

   Will model outputs be suitable for matching with action costs for a cost benefit analysis?

7. The Water Authority would like to know the vital rates for the various age-classes of RGSM with a sensitivity and elasticity analysis to demonstrate which age-class will contribute the most to fitness and population growth. I believe this information is critical for making management decisions that require trade-offs.

   We would like to know estimates of variance from demographic and environmental stochasticity, and how that impacts vital rates for each age-class. Understanding these parameters could help with narrowing uncertainty when enacting different management decisions to maintain or improve vital rates, especially when trade-offs are involved.

   We would like to know how habitat availability affects vital rates for different age classes. There is a lot of evidence that inundated floodplain in spring is beneficial to larval survival, but what is the relationship between area of inundated habitat and successful recruitment? There is a lot of uncertainty with respect to which habitats may improve adult survival throughout the year. I would like the model to be able to test alternative hypotheses for habitat and adult survival through different seasons.

   Overall, we would like the model to be a tool for testing competing hypotheses with respect to population dynamics, population management, habitat restoration, and water management activities.

8. What is the RGSM population benefit for a unit volume of water?

   Is this an annual volume of water? Or a periodic requirement (2-3 year intervals)?

   What are the trade-offs for using water (volume) for recruitment flow versus reducing river drying?

Will the model support identifying alternative strategies for floodplain inundation for RGSM recruitment?

9. The habitat requirements for the silvery minnow throughout the year and how the availability of habitat affects the population of RGSM. On habitat we need to know the category of habitat we are discussing, for example in-stream vs off-channel type of habitat. This then relates to the time of year these habitats can be occupied. Also water quality, width-length-depth of wetted river channel, food sources, etc.

   The question above are good, are they achievable with this model?

   How much information and how reliable will modeling fish response to flows be?

Appendix A: Tables of Science Panel Recommendations

Table A-1. Recommendations and observations from the Hubert et al. (2016) Population Monitoring Science Panel. The 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	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	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	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	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
Observation Beyond the Scope 1	31	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.	--	--

Number	Page	Recommendation	Panel Priority	PMWG Priority
Observation Beyond the Scope 2	31	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.	--	--
Observation Beyond the Scope 3	31	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 1186 MRG.	--	--

Number	Page	Recommendation	Panel Priority	PMWG Priority
Observation Beyond the Scope 4	31	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 (Quinones et al. 2014; Trushenski et al. 2015; Carmichael et al. 2015)...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.	--	--
Observation Beyond the Scope 5	32	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 m2 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.	--	--

Number	Page	Recommendation	Panel Priority	PMWG Priority
Observation Beyond the Scope 6	32	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).	--	--
Observation Beyond the Scope 7	33	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.	--	--

Number	Page	Recommendation	Panel Priority	PMWG Priority
Observation Beyond the Scope 8	33	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.	--	--
Observation Beyond the Scope 9	33	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]).	--	--

Number	Page	Recommendation	Panel Priority	PMWG Priority
Observation Beyond the Scope 10	33	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.	--	--

Table A-2. Recommendations from the Noon et al. (2017) Adaptive Management Science Panel. The 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. Recommendations from the Fraser et al. (2016) Genetics Science Panel. The Science Panel assigned priorities to these recommendations, but priorities were not assigned by the Genetics Work Group (GWG). Priority: 1 = high, 2 = moderate, 3 = low.

Number	Page	Recommendation	Panel Priority	GWG Priority
Reporting Rec. 1	4	Sometimes it is not clear how Ne estimators relate to purpose. The reports could improve the explanations for why certain approaches were adopted.	1	--
Reporting Rec. 2	4	Develop a biological relevant and realistic benchmark for critically low levels of genetic diversity. One possible way to set a benchmark would be to estimate the 95% confidence interval (CI) for genetic diversity (expected heterozygosity [He] and number of alleles [Na]) using all samples across time and space. If the diversity falls below the CI, then more aggressive management actions may be warranted.	1	--
Reporting Rec. 3	4	There needs to be a clear statement of the hypothesis and predictions being tested. For example, a simple hypothesis is whether there is a difference in estimates of genetic diversity between the pre- and post-augmentation periods. If this is the case, one approach would be to use a linear model to compare the estimates pre- and post-augmentation. Although time should be included as a co-variate, there is no effect of augmentation on observed heterozygosity corrected for sample size (Hoc) ($t = 1.95$, $p = 0.071$).	2	--
Reporting Rec. 4	4	The authors need to redefine pre-augmentation (1987, 1999) and augmentation periods (post 1999) given the augmentation that took place in 2000 and 2001. They may not be able to conclude strongly whether genetic diversity of the natural spawning population has changed. However, the authors can say that augmentation has maintained genetic diversity throughout the augmentation period, with the provision that this conclusion is based on the nine microsatellite loci evaluated, which might not reflect genome-wide variation.	2	--

Number	Page	Recommendation	Panel Priority	GWG Priority
Reporting Rec. 5	4	Microsatellite loci may no longer be the most effective markers for the purpose as the cost of newer, genotyping-by-sequencing (GBS) approaches has become more affordable for largescale throughput of many individuals. The limitations of microsatellites relative to other genetic markers such as single nucleotide polymorphisms (SNPs), and trade-offs associated with different genetic markers in relation to RGSM genetic monitoring goals, are discussed in detail under Questions 2, 8, 9, 10, and 13 (particularly 13).	2	--
Reporting Rec. 6	4	The Genetic Project PIs may also wish to examine genetic diversity / Ne variation over time using a piecewise regression as these can be used to find any breakpoints in the data; also referred to as segmented regression. If a breakpoint is identified say for pre- versus post-augmentation, then separate regressions can be run for each section. This approach can also identify points in time where there are temporal changes in genetic diversity.	3	--
Question 13 Rec. 1a	16	The panel therefore recommends that both neutral and adaptive genetic variation be monitored over time in RGSM in the future using a larger, more diverse set of genetic markers. Genotyping-by-sequencing (GBS) or related equivalent would provide more confident estimates of genome-wide neutral genetic variation (Nac, Ho) in RGSM because it would more likely represent the entire genome (for more information on GBS and related NGS approaches and their practical benefits for conservation genetics monitoring, see the review of Allendorf et al. 2010)...thus we recommend examining phenotypic variation for important life history traits (size/age maturity, growth rate), behavioral traits (anti-predator behavior, risking taking behavioral syndromes) and morphology (body shape as it relates to flow regime).	2	--
Question 13 Rec. 1b	17	Sampling of floodplains should be considered and included where feasible to ensure that the genetic characteristics of RGSM are adequately represented in egg collection samples.	1	--

Number	Page	Recommendation	Panel Priority	GWG Priority
Question 13 Rec. 2a	18	Conduct random sampling of annual egg collections from nature, to include not only the main channel but also the floodplains, for subsequent hatchery rearing (e.g., current collections only come from the main channel of the Rio Grande River, not on floodplains).	1	--
Question 13 Rec. 2b	18	Rear RGSM in environmental conditions that resemble natural environmental conditions as much as possible. This will reduce relaxation of selection or non-random survival at egg/early life stages in relation to habitat selection/settlement, behavioral/physiological characteristics, anti-predator responses etc. Specific recommendations for RGSM hatcheries include: (i) early juvenile environmental enrichment that resembles critical floodplain habitat (temperature, substrate, flow, turbidity, pH, conductivity, food sources, natural daylight); and (ii) some exposure to natural predators, or at the very least, mimicking of predators to stimulate anti-predator conditioning.	1	--
Question 13 Rec. 2c	18	RGSM live longer in captivity and the breeding program uses 4-year old fish as brood stock. By contrast, in the wild the breeding population is comprised largely of 1-year old fish. Thus, it will be prudent to evaluate the phenotypic effects of older brood-stock. Also, because larger fish have about 4x as many eggs as younger adults (10,000 vs. 2,500), and there is also likely higher variance in egg production among 4-year old fish compared to the variation in egg production among 1-year old fish. This could undermine efforts to equalize family sizes. Thus, using younger fish as brood stock will reduce the likelihood of un-intentional domestication selection, and also result in higher effective population sizes (due to reduced variance in egg production among females).	1	--
Question 13 Rec. 2d	18	Equalize contributions of different adults in the captive broodstock to new broods/lots as much as possible.	1	--

Number	Page	Recommendation	Panel Priority	GWG Priority
Question 13 Rec. 2e	18	Rear RGSM so as to maintain the growth trajectories typical of wild-raised fish (i.e., Age 1 fish in captivity should exhibit the same range of sizes of Age 1 fish in the wild). At present, either faster growing individuals may be unintentionally selected for, or other fish phenotypes (e.g., size, condition, body shape) may not match natural sizes upon release.	1	--
Question 13 Rec. 2f	19	Rear RGSM on natural diet if possible; diet appears natural at early life stages, but diet appears supplemented in later life stages (pellet feed).	1	--
Question 13 Rec. 2g	19	Minimize the duration in captivity as much as possible before release; domestication selection is reduced with less captive exposure (see Frankham 2008 and Fraser 2008).	1	--
Question 13 Rec. 3a	19	Maximize the information gained from re-stocking efforts of hatchery-raised fish back into the river in order to test particular scientific hypotheses and inform adaptive management.	2	--
Question 13 Rec. 3b	19	In addition (or alternatively if resources are limited), the genetics survey could focus on characterizing whether the year classes maintained in the hatcheries change over time in their genetic constitution as a consequence of differential mortality.	2	--
Question 13 Rec. 3c	20	Monitoring of domestication selection could include DNA fingerprinting (GBS) of wild-caught egg collections. An investigation into whether non-random changes to genome-wide variation were occurring at successive early life stages relative to the same stages in the wild would provide evidence that the hatchery environment is resulting in domestication selection.	3	--

Number	Page	Recommendation	Panel Priority	GWG Priority
1	23	A flow chart should be constructed for each year that gives detailed numbers for: eggs and dates taken, disposition of eggs/larvae to specific rearing sites, broodstock maintained, actual breeding strategy, disposition of eggs/larvae to specific rearing sites, pooling of larvae prior to stocking, stocking sites, source of juveniles, and dates. These data should be standardized and collected for each hatchery engaged in fish production and the data should be made available electronically to all interested parties. Deviations from planned methodologies (such as the inclusion of approximately 10,000 eggs from unplanned spawning in a broodstock tank) should be noted in the flow chart.	1	--
2	23	When deviations from planned methodologies result in the production of offspring, those offspring should not be released into the wild. Release of these offspring into the river could have a negative effect on the overall genetic diversity of the population. Providing flexibility in the next recovery permit should allow such surplus fish to be properly handled, whether used for research or held until natural death in the hatchery.	1	--
3	23	All broodstock and sufficient subset of the pre-release juveniles should be genotyped and the contribution of each broodstock individual determined. These results can be used to gain a more accurate, precise and biologically relevant estimate of Ne for each year class. This approach avoids the inherent assumptions and excessive variance associated with the Ne estimators currently employed. This should be done every year. Developing a high throughput method would facilitate more rapid genotyping.	1	--
4	24	The Genetics Management and Propagation Plan and/or the Augmentation Plan should have a detailed methodology as to what will be done should a drought lasting more than three/four years occurs or all four year classes of broodstock are lost to a major hatchery accident.	1	--

Number	Page	Recommendation	Panel Priority	GWG Priority
5	24	The Science Workgroup (led by the Program) and the Genetics Workgroup (led by the USFWS) should integrate the genetics data and the decision-making more carefully. Specifically, there should be more translation of the genetics research into the adaptive management process, hatchery broodstock practices, and the integration of the past 15 years of research (genetics and ecology combined).	1	--
6	24	A more stable, consistent funding stream for the genetics research (e.g. an extended funding cycle) would ensure that all critical, temporally important genetic studies are accomplished each year (e.g., broodstock genotyping, pre-release juvenile genotyping). Cost will vary depending on the analysis and goal. At the time of writing this report, the RGSM program can expect to require approximately $50-150/individual for GBS or RAD-seq if outsourced to a genomics facility (including individual sample preparation, but not including salary for a research associate for sample preparation, data filtering and data analysis); a minimum of 30-40 individuals per year is recommended. Other genetic assessments do not require the amount of genetic data generated from GBS; any parentage assignments of offspring generating from mixed matings in the hatchery, for example, would be expected to cost approximately $5-10/individual (not including personnel salaries), and so could be (and should be) conducted on larger numbers of individuals (1000s).	1	--
7	24	The use of only four year fish as broodstock may compromise the maintenance of genetic diversity because of the possibility of non-random, differential survival of individuals in the hatchery. Crosses should include younger fish. As a consequence of using younger fish as broodstock with lower fecundity, more fish will be needed to produce the quota of eggs and this will increase the effective number of breeders.	1	--
8	24	It will be useful to conduct an evaluation of whether domestication selection is occurring in the hatcheries. This could be done using an appropriate genetic analysis and/or measuring quantitative traits to assess phenotypic variation of each captive cohort during each year in captivity.	1	--

Number	Page	Recommendation	Panel Priority	GWG Priority
9	24	We recommend the use of the term “naturally spawned” in place of the term “wild” to refer to fish captured in the river that do not have an elastomeric tag; this assumes that all augmentation fish received a tag. It is likely that all fish captured in the wild have experienced some hatchery influence in their ancestry.	2	--
10	25	If possible, the augmentation team should consider artificially spawning broodstock in a one female by one male mating scheme, all the while maintaining the same total number of broodstock adults spawned (or increasing this number). This would allow equalizing family size as families are combined.	2	--
11	25	Relatedness should be calculated for broodstock prior to use to choose specific crosses that avoid inbreeding. If group spawning continues, relatedness estimates could be used to ensure that potential spawners in a group have low kinship.	2	--
12	25	To facilitate adaptive management, experimental studies comparing the survival and reproductive success of subsets of RGSM from different stocking strategies and hatchery facilities in nature would also shed light on the extent to which domestication selection is a concern in the recovery program.	2	--
13	25	A study using next-generation sequencing technology (e.g., GBS, RAD-seq) should be done with pre-augmentation samples and post-augmentation year classes to determine how the genome as a whole has changed over time. At the time of writing this report, the RGSM program can expect to require approximately $50-150/individual for such an assessment (more for RAD-seq) if outsourced to a genomics facility (including individual sample preparation, but not including salary for a research associate for sample preparation, data filtering and data analysis); a minimum of 30-40 individuals per year is recommended.	2	--