Documents:

Meeting Minutes

Read Aheads and Presentations

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PVA Biology Work Group Meeting

May 4-5, 2010
U.S. Fish & Wildlife Service – New Mexico Ecological Services Field Office
2105 Osuna Road NE, Albuquerque, NM 87113

Meeting Objectives

• Workgroup Business	• Identifying Critical Data needs for PVA Models
• Discuss future interaction for PVAs and PHVA	• Construct timeline for development of data
• Review and Discuss RGSM Population Data	• Create a schedule for development for both PVAs

Decisions

The PVA-Biology workgroup approved all past draft minutes as final.

The PVA-Biology workgroup requests that all recommendations for data and research needs be forwarded to the Science workgroup (ScW) via the Coordination Committee (CC).

Actions

Dr. Goodman will email the RGSM plot files from 1992-2008 to members so they can evaluate them and add additional historical data

Jason Remshardt will provide data to Dr. Goodman on how many fish were moved (salvage data)

Jason Remshardt will assist Dr. Goodman with incorporating egg drift data into the RGSM density plots

Yvette McKenna will find out who has the data on fin clips from the RGSM genetics work being done by T. Turner and if the Collaborative Program has access to them; some data is published in the Proceedings of Royal Society of London: Turner et al., 2006

Dave Campbell will send a formal request to Reclamation requesting a co-chair from Reclamation be appointed to the PVA workgroup and Jeanne Dye will follow up in Reclamation to determine the appropriate staff level for the position

Stacey Kopitsch will send the list of "variables for consideration" to workgroup members for review.

Jeanne Dye will try to find additional tagging data that was not included in population monitoring or estimation. She will also see there if is information on who specifically does field work for data that is used for genetic studies.

Michael Hatch will make available data from egg monitoring as it relates to water discharge

Rich Valdez will incorporate the list of hypotheses into the list of questions and send to the workgroup for review

Next Steps

Meeting Summary

Day 1:

- The meeting was called to order and introductions were made around the table. Dave Campbell, U.S. Fish and Wildlife Service (Service) was introduced as the new Federal Co-Chair for the PVA Work Group. The agenda was modified to postpone the workgroup business until later and start with the review and discussion of Rio Grande Silvery (RGSM) Minnow population data.
- Dr. Goodman presented a review of the RGSM population data and explained that this data would contribute to exercises for modeling future of the RGSM population.
  - Dr. Goodman showed two graphs made from population monitoring data gathered from the Angostura, Isleta, and San Acacia reaches. The first graph showed RGSM population density per

year for the month of October, starting in1993 and ending in 2008. The second graph showed the MRGSM census during the spring reproductive period. Concern was expressed about using density estimates based on CPUE calculations as a basis for estimating population trends.
    - The workgroup was then shown RGSM density plots by reach and year. Dr. Goodman went through each plot from 1992-2008 and posed questions to the group on trends in the plots that may be explained from historical knowledge.
    - The graphs and density plots can be found on Dr. Goodman's website (www.esg.montana.edu/rgsm/samres/asirm2.html).
- Megan Osborne, Research Assistant Professor, UNM presented on the "*Management of genetic resources in the federally endangered Rio Grande Silvery Minnow, Hybognathus amarus*". The presentation provided a summary of the RGSM genetic studies and their findings that have been conducted by Megan and Tom Turner, Associate Professor, UNM.
- Phil Miller provided a short power point presentation that outlined how adding age classes to the RAMAS population demographic model can lead to measurable changes in the predicted growth trajectory.
- The MRGESACP video was viewed.
- The workgroup performed an action item review.
- Dave Campbell is the Federal co-chair; David Gensler is the MRGCD co-chair; a co-chair is not currently designated from Reclamation.
- Group decided to hold off on approval of the Charter until it is determined whether Reclamation will remain as one of the Federal co-chairs as originally designated. Dave Campbell will send a formal request to Reclamation requesting a co-chair from Reclamation be appointed to the PVA workgroup and Jeanne Dye will follow up in Reclamation to determine the appropriate staff level for the position
- Suggested revisions to the workgroup work plan were circulated by Dr. Goodman; his changes will be accepted. The workgroup would like to postpone approval of the Annual Work Plan until after a discussion of path forward for both PVA models

<u>Day2:</u>

- The meeting began with a discussion on developing a path forward for both PVA models. Brian Millsap, Deputy Regional Director for Service stated the Service is expecting to receive Biological Assessments (BA) from the Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (USACE) at the end of September 2010. The Service would like to use the PVA models in the evaluation of management actions included in the BAs. The question of what type of product will be available by the end of September to use for evaluation was posed for discussion. It was agreed that FORTRAN and RAMAS model platforms would be available by September 30, 2010, with the caveat that more data over time will improve the model outputs.
- There was discussion on the how the PVA workgroup would relate to an adaptive management workgroup. It was pointed out that PVA workgroup has a very good understanding of the data, hypotheses, and questions which would contribute to an adaptive management process.
- Dr. Miller presented a list of "variables for consideration" which outlined the data they would like to focus on in order to have the PVA models available by the end of September 2010. Workgroup members will review the list of "variables for consideration". Stacey Kopitsch will send the list of "variables for consideration" to workgroup members for review.
- It was suggested that the group formalize the list of hypotheses that were generated at the January 27, 2010 PVA/Biology workgroup. It was thought that the list of hypotheses and list of questions would be central to the adaptive management process and that the hypotheses should be incorporated into the questions. Rich Valdez will incorporate the list of hypotheses into the list of questions and send to the workgroup for review.
- The workgroup then discussed research needs. Jeanne Dye will try to find additional tagging data that was not part of population monitoring or estimation. She will also see if there is information on who specifically does field work data gathering for genetic studies. Michael Hatch will make data available from egg monitoring as it relates to water discharge.
- The PVA-Biology workgroup requests that all recommendations for new or additional data and research needs be forwarded to the Science workgroup (ScW) via the Coordination Committee (CC).

- Discussions on age specific survivorship, hydrologic demographic response, and egg dispersal will be on the June Agenda.
- Phil Miller showed a brief presentation that showed a proposed mechanism for integrating hydrologic model output with the RAMAS model.

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Next PVA-Biology Meeting June 29-30, 2010

PVA-Biology Meeting Minutes

Day One: Morning

Introductions, Review Agenda

- Dave Campbell called the meeting to order and briefly introduced himself. Introductions were made around the table.
- Workgroup business will be shifted on the agenda and the meeting will start with the population data review.
- It was asked if the people who collected population data were intending to be at today's meeting.
  - It was answered that the people who collected the data would not be attending this PVA meeting.
  - There was a suggestion for a meeting to discuss the historical data with the collectors.

Review and Discussion of Middle Rio Grande Silvery Minnow Population Data – Dr. Goodman

- To begin Dr. Goodman briefly explained that the workgroup was engaged in a modeling exercise to model future populations of Rio Grande Silvery Minnow (RGSM). Dr. Goodman explained that one test of the credibility of a model's prediction is the model's ability to reproduce the historical record. If the model can't reproduce historical record, it casts doubt on the model's ability to predict future trends. There are 2 steps to test the model; first, use past data to estimate parameters and second, actually run the past environmental data and see if the model reproduces the past trajectory. In the world of population modeling the fitting of the trajectory is called integrative modeling or data assimilation. There is population monitoring data going back to 1993 for this population of minnows. The Service's monitoring data is not incorporated in the data Dr. Goodman is showing today. Dr. Goodman wanted to model 3 reaches as distinct but interacting models. Dr. Goodman then presented two graphs made from population monitoring data from the Angostura, Isleta, and San Acacia reaches.
- The first graph showed average RGSM population density per year for the month of October, starting in1993 and ending in 2008. Dr. Goodman pointed out that there are gaps in monitoring for the years 1998 and 2009. A discussion about continuity of monitoring was suggested; data gaps are something the Program cannot afford, especially in regards to adaptive management. The graph shows considerable volubility and volatility within reaches. Sometimes there is synchronicity among reaches; 2005 was a good year for all reaches, 2006 was a bad year for all reaches. In the early 1990's the reaches are not in synchronicity. It was not thought that flow data could explain the break down in synchronicity of the reaches.
- The second graph is the census during the spring reproductive period, restricted to numbers that were recorded as age zero. This graph just shows the young fish born in the window of May 15 and August 15. This graph is an attempt to capture the breeding pulse for each year. In the 1990s San Acacia looks good while Isleta and Angostura are low. Between the two graphs there has been a loss of half the fish, this is not unusual for larval fish. The spring reproduction translates pretty directly into the fall census in terms of both reproduction and population density.
- **Question**: To what degree do you ascribe sampling variance as a way to describe inter-annual variability in density observations? It sounds like variability by reach and year is trying to be explained in the context of environmental processes. There's been concern expressed in this group about using these types of data to make conclusions.

- **Response**: First superficially, just eyeballing the top graph, we see things that can't be sampling variability because they are too consistent. For example in 2005 all 3 reaches had a good year and all 3 reaches say it's a good year to reproduce. There is a signal coming through. The same thing can be said about bad years. For example in the San Acacia reach in the early 1990's there's a signal. It's unquestionable that there is noise. You can see noise by looking at individual samples. What is shown here is the average over a certain amount of sampling variation. By using an integrative model we can get serious statistics. Inside model continuity, these dynamics are drawn by birth rates and death rates in population. What birth and death rates do we need to get close to the observations we saw, taking into account when observations are consistent, or more, or fewer or less consistent?
- It was asked if the PVA workgroup was comfortable with using density estimates based on CPUE calculations as a basis for estimating population trends over the time period of data collection.
  - There's other data that I do want to fit into this modeling. I would like to fit the model to the FWS data and these simultaneously. What I'm proposing is to use all the data and come up with a model that estimates parameters and reconciles all data sources giving each its own weight.
  - One opinion was that this question would best be answered by the people who collected the data.
  - It was pointed out that the conversation about how flow at time of sampling is a confounding factor is a conversation that the workgroup has had before. It was felt that this is a question that needs to be answered.
  - It was said that there is reason for skepticism and suspicion. The way to deal with it is to analyze the consequence of the suspicion to see if the data is consistent with it. All that's shown is the October monthly aggregate and spring monthly pulse. This detail should be used to see how much responds to flow and ask if the response to flow is an artifact that is distorting results or a cause and effect that changes the data. This data should not be dismissed for theological reasons.
  - It was said that these two data sets are the making of a stock recruitment model. In that arena, what becomes important is the relationship of these two data sets. More so than the accuracy of these points. It was agreed that the accuracy is a concern but that it also depends on the manner in which these data are used.

- The workgroup then looked at RGSM Density Plots and the Sample Event Data. Dr. Goodman reviewed points of interest in the Density Plots using the Sample Event Data to show details.
  - In late July in 1993, there's a pulse in the Isleta reach. In July there were 4 samples taken, almost all caught fish of age zero. The Sample Event Data shows this was a reproduction pulse. Here we have the opportunity to see variability and consistency between samples.
  - It was pointed out that the data as it is now does not differentiate whether a larval seine was used. The standard is if larval fish are present, the catching of the larval fish is in response to 5% of the total effort. In the Sample Event Data there are flags to interpret the data. It's recorded when the larval seine is used, there are isolated pools, the site is dry, or when there was no sampling. The flags are also information, for example they show when there were isolated pools.
  - In May of 1996 there are lots of fish in Isleta. If we look at the tables for Isleta in May of 1996 there were 4 samples which caught no baby fish. So this is not a reproduction pulse. I talked to Rob and found out that this was a drought year. All the water in Isleta was diverted at the dam. The water had retreated to a pool below the dam and that is where sampling occurred.
  - Years that are way below spring flow do not have much reproduction
  - Years when the flow drops to very low levels are when there is high variability. There is a concentration of fish in occasional pools. Let's look at July 1993 in San Acacia. That is one event that is off the scale. Looking at the data, no pools were flagged, need to call Rob Dudley to see what was going on.

    - In years with above average spring flow there is usually reproduction.
    - 1997 – the flows look normal, not much response in population except in San Acacia where there is good reproduction and carrying over (older fish found). Then there is a drop from 6000 to 1000 cfs.
        - What actually is happening in river?
        - Sometimes the drop is natural and sometimes it's a valve being shut off. This drop looks natural, it falls quickly but slowly tails out at the bottom.
    - 2004 - there's a dry spell. The flow is terrible and the minnow are not doing so well. The spring pulse is not very big, but it looks like the fish are ready to spawn. It seems like if there's enough fish left and even a little bit of water they will reproduce even in Angostura. Data from the table shows that for Angostura reproduction picked up in late May.
    - 2005 seems like a banner year for everyone. There's good flow. There is still dramatic reproduction after June when flow has ended.
    - In 2006 there was lots of carryover; there was also low water.
    - In 2007 the water is better and there is also some reproduction.
    - Is the seesawing that we see in San Acacia and Angostura due to habitat changes? Angostura is where most habitat projects happened. We need to know when habitat projects went online to see what was happening before and after. Upper reaches may have effects from augmentation; maybe their presence contributes to spawning.
        - If that's true this data says that the fish that are being put into the river are reproducing.
        - We are in the 3rd year of not stocking the reach.
        - **Question**: So that inverse relationship between San Acacia and Angostura isn't consistent? Sometimes Angostura dries.
            - **Response**: The seesawing isn't seen year to year, it's seen more from decade to decade. In 2004 is the first time that Angostura is looking flush, except in 1995. Obviously flow is many faceted. Something that could be done is to start testing high flow, low flow, etc, to see which is having an effect.
- **Question**: How do you plan to represent augmentation as opposed to years when there was not augmentation?
    - **Response**: There is a record of when and how many fish were stocked.
    - It would be possible to look for those stocked fish showing up in monitoring data and Service data as well. In monitoring data there are only a handful of spots where the tagged fish have been caught; either certain locations are favored or the fish are hanging out where they were released. This data doesn't tell us where the released fish are reproducing or where their offspring go.
- **Question**: Many of us are curious about how hydrology data are used in analyses of these catch rate indices. In looking at this there is some relationship between flow and reproduction in the population. What are your thoughts on this?
    - **Response**: This is going to have to be taken into account in 2 ways in the model. Flow creates artifacts, when there is pooling you see huge congregations of fish, these fish shouldn't be extrapolated. Affects interpretation. The model also looks for flow correlates that explain reproduction. We don't know what that correlate is, we are going to have to try different indices.

<u>Rio Grande Silvery Minnow Genetics</u>

- The workgroup viewed a presentation "*Management of genetic resources in the federally endangered Rio Grande Silvery Minnow, Hybognathus amarus",* by Dr. Megan Osborne. The presentation gave a brief summary of genetic studies and their findings on the RGSM. *For details please see the attached presentation. Also any of Dr. Osborne's and Dr. Turner's applicable publications can be found on the Program website.*
- *The following is discussion that occurred after the presentation.*

- **Question**: Can you detect genetic differences between reaches?
  - **Response**: There is no genetic structure between reaches. We have attempted to see if there is a difference in the amount of genetic difference between reaches. However it's complicated, because sample sizes in lower reaches suffer when there is low water.
- **Question**: Does augmentation deliberately transplant between reaches?
  - **Response**: Yes. The majority of the fish stock came from San Acacia reach. Early on we tried to sample and get fish from all 3 reaches. But there is some artificial transfer from San Acacia reach to Angostura reach where they wouldn't naturally occur. Especially when eggs collected for propagation were collected at the downstream edge of the system. There was some purposeful artificial movement but some of it was out of necessity.
- **Question**: There was disconnect between the effective population size and the census size. How might Dan's data change this data?
  - **Response:** There would still be a much lower effective population size than census size. There's an over estimate of the ratio of effective size to census size. What we're showing is there are more fish out there that are contributing offspring, that's basically what the analysis says.
  - Fish come together before spawning. The clumps are slightly genetically different from each other; it's a sampling process, that's how we model at this point. You don't see much difference among reaches because the fish move down, and then we move the fish back up through augmentation.
- Dr. Osborne and Dr. Turner were thanked for being very prolific in publishing their work.
- **Question**: I'm trying to reconcile this issue of N_e/N relative to population size.
  - **Response:** That's the variance.
- **Question**: Does that refine?
  - **Response**: Yes, it makes it even smaller.
- **Question**: That's a huge concern isn't it? If you look at just the literature and what the literature says about effective size, shouldn't we all be pretty panicked?
  - **Response**: There's a very strong demographic process that's working out there. This has been shown in marine species, oysters. Species with this life history, high fecundity, these are species that are susceptible to differential between effective size and census size. Our data shows there is this difference. The estimate for effective size is much tighter than for census size. We know this estimate shows strong effect
- **Question**: I thought it would be necessary to have a large wild group?
  - **Response**: Once diversity is lost it takes a long time to recover. We are trying to maintain the level of diversity. For example, taken that ratio N_e/ N, if you have a ratio that's equal to 0.001, need to have efficient level of N to keep 0.001 going. What we have been able to do, is estimate N_e on variance effective size. This is relatively constant in the wild. Supplementation has put alleles back into the wild that were gone in 2002. There's disconnect between inbreeding effective size, and effective population size. If captive breeding stops diversity will be lost.
- **Question**: Will you be able to tease out regional or reach affect?
  - **Response:** It's probable, with the fish that spawn upstream, that their offspring will end up further downstream in large numbers. With augmentation fish go down then go back up, there is high gene flow between reaches, so there is not diversity between reaches.
- **Question**: When you calculate N_eV that's based on a sample, those fish came from places; what happens if you analyze that sample of spatial stratification?

        - **Response:** It depends on how structured the populations are. If they are strongly divergent from one another and if the probability of extinction is low, the spatial structure among reaches is low. The highest spatial structure is between spawning aggregations. Individuals clump up at random prior to spawning. These clumps have a slight genetic difference between them.
    - **Comment**: From a long term viability stand point, the importance of this kind of genetic characteristic of populations depends on long term fitness.
        - **Response:** It's the inbreeding effective size that's most important. In the years 1999-2002 heterozygosity was lost, had a low inbreeding effective size. This was recovered through augmentation.
    - **Question**: Do you see value in doing experimental work where you can look at the magnitude of inbreeding?
        - **Response:** It's something to look at, but there's the risk of fish getting out if purposefully inbreeding.
    - **Question**: Do you guys know what strategies fish are using for spawning in the wild?
        - **Response:** It seems like they are group spawning but it's hard to observe in the wild. I expect they come together in aggregations and start mixing.
    - **Question**: Do you have a sense of the number of fish in an aggregation
        - **Response:** Between one hundred and two hundred.
    - **Question**: You've expressed concern in some of your publications over swamping the wild population with captive reared fish. Do you know enough to understand the balance of suitable numbers of captive fish that could be released?
        - **Response**: It turns out that where the fish are from is important. We took samples of eggs from that point and looked at over time series, sampled at various points; each group of eggs appears to be genetically cohesive. We think this reflects movement of production downstream from areas of spawning aggregates. There's hardly any effect in that case.
        - There's an interesting relationship between captive stock of wild caught eggs and the wild fish. The captive fish live longer so they spawn more, you get a storage effect in captive stocks. We refresh these constantly. We think that the captive program and scale is sufficient to maintain the total diversity we see.
        - If we have to go captive the best strategy is to take eggs from the wild, rear then release. If we can't get enough eggs from the wild then we go to captive spawning.
    - **Question**: Is there a cap on the number of individuals that are released to avoid or minimize swamping?
        - **Response**: If the captive stock is not refreshed there's inbreeding and they are not released. We can't really say a number based on anything that we've done.
    - **Question**: There's a pretty significant amount of downstream movement both in eggs and hatched individuals. What about upstream movement?
        - **Response**: There is artificial upstream movement through augmentation.
    - **Question**: Is there any way to use genetic data and parse out artificial movement to estimate dispersal?
            - **Response**: We imagine that you could but it would be an experiment where individuals are marked. It would be very difficult to do from these data.
    - **Question**: Are there any results on the Big Bend fish? Their genetic diversity levels?

        - **Response**: They are comparable to other captive stocks that were released and look pretty good.
        - There is no documented reproduction yet.

Day One: Afternoon

Density Plots by Reach and Year

- The workgroup revisited the Density Plots presented earlier in the meeting by Dr. Goodman.
- It was said that the workgroup needs to begin a process to assemble a narrative as a group regarding population data; there is still important data that has not been captured in the already existing files (i.e. population monitoring, population estimation, etc.). Accumulate a story by year; need to know how much river drying is taking place each year; why was the water managed in the way that created the flow patterns we see; how were management decisions affected based on the weather each year. Dr. Goodman went through each plot from 1992-2008 and posed questions to the group on trends in the plots that may be explained from historical knowledge.
    - 1993 – Why did the drying occur in 1993? Was it due to weather or management decisions?
        - 1993 was the year the fish were listed; there would not have been any species related management actions that year.
    - 1994 – This appears to be a good year for water, but there appears to be an abrupt stop of water at the end of June. Reproduction is good in Isleta and San Acacia reaches. There are not isolated pools in San Acacia so the high numbers may be taken at face value. Even with low flows in July, there's still good recruitment. What was the cause of the abrupt shut down in June and why is Angostura not doing well with regard to reproduction compared to other reaches or compared to itself the year before?
        - Abrupt shutdown of water is not good for Angostura reach; drop in flow at the end of May might indicate multimodal hydrograph.
    - 1995 – There is abrupt shutdown of flow at the end of July; there is still good reproduction in Isleta and San Acacia reaches.
        - 1995 does appear to be more of a monomodal hydrograph.
    - 1996 – There are peak flows for that spring in February.
        - Was there reproduction in February in San Acacia reach? There was no reproduction just carryover from the year before, therefore there was good survival from 1995-1996.
        - In San Acacia reach in May of 1996 only one sample showed reproduction, 200 fish in a 700 sq/m hotspot; sporadic reproduction taking place.
        - May in Isleta reach – the river was running dry before the Isleta dam in April/May and fish were concentrating below the dam, therefore no reproduction;
    - 1997- This was an average water year in terms of peak flow, but narrow peak and reproduction determined in early July in Isleta and San Acacia reaches.
    - 1998 – No data available.
    - 1999 – There was average water except for an extra pulse in August. Isleta reach shows a late burst of reproduction in August that was not detected in July. There's a normal reproductive peak in July in San Acacia reach. Angostura reach continues to be low compared to other reaches.
        - One opinion was that the variation could be based on incipient level of floodplain coupling. A small amount of water does better in Angostura. Downstream drift may be evident in San Acacia reach. There is more drying in San Acacia reach than in any other reach. You will see variation occurring whether hydrograph is monomodal or multimodal; with multimodal hydrograph you will see more larval fish entering the drift. It seems the reinundation breaks the fish loose- a lot of that is conjecture, but some is backed up by data. These are patterns recognized in nature or deviations in nature; recognition of

patterns or deviation in patterns; if there is an abrupt cutoff in flow and the river is bounded by an active channel there will be an effect. The response is related to duration of coupling; it seems that adult fish on the floodplain during spawning need time to move there, time to spawn, and time to incubate. There is a marked difference at or greater than 12 days.

- 2001 – This year has low flows when compared to other years. There appears to be a reproductive burst at the end of June in San Acacia reach, the minimal water in San Acacia reach was enough to spur consistent reproduction up and down the reach. There may have been an engineered pulse in May.
- 2002 – The water flat-lined this year.
- 2006 – Why are flows highest in San Acacia reach compared to Angostura and Isleta reaches?
- 2007 – There was good October census in Isleta reach despite numerous drying.
- 2008 – This year had better than average water, good reproduction, and good survival in all reaches. But the last census was at the beginning October.

- *The following is discussion that occurred after the presentation.*
  - It was one opinion that looking at the length of the fish may suggest the timing of spawning to be very different. It was suggested to produce a histogram based on spawning data; if we are going to link with hydrograph, that is the critical aspect of this analysis. Spawning timing can be back-calculated in years where we have lengths. There are evidently failed spawning events that take place, by looking at egg drift numbers you can see those eggs don't show up later as larvae. It's important to get down the time of spawning. There needs to be more sampling intensity in the spring and the lengths of the fish need to be documented.
  - It was commented that in 2006 there was minimal runoff, but the largest spawning event observed was on June 3rd / 4th in response to a heavy discharge event. It occurred high in the water shed in Socorro. The fish spawned in response to this thunderstorm runoff event. The reach dried up right after the event and the fish were eyelash sized. RGSM is an opportunistic spawner, if spring spawning fails RGSM may attempt a second spawning if water is available later in the season. If we can detect failed spawning events and document what kind of flow preceded the spawning we can identify why the spawn failed
  - Jason Remshardt will assist Dr. Goodman with incorporating egg drift data into the RGSM density plots.
  - Dr. Goodman will email the RGSM plot files from 1992-2008 to workgroup members so they can evaluate them and add additional historical data.
  - Jason Remshardt will provide data on how many fish were moved to Dr. Goodman (salvage data).
  - It was commented that hatchery data is available. COA was responsible for initial collection of eggs for propagation; some of the eggs get transferred to a federal hatchery (i.e. Dexter). Egg collection data from the hatchery will add to completeness of the data.
  - The Genetic group will be going to 3 sites in each of the reaches collecting fin clips. The group will not be distinguishing age/length. It was asked if the genetic data will inform these graphs.
    - Only if lengths are taken. It may be worth pursuing that data as well.
  - Yvette McKenna will find out who has the data on fin clips from the RGSM genetics work being done by Tom Turner and does the Collaborative Program have access; some data is published in the Proceedings of Royal Society of London: Turner et al., 2006.

Results of a sensitivity analysis for impacts of minnow longevity on population demographics using the RAMAS model

- Dr. Miller had a short power point presentation that outlined how adding age classes to the RAMAS population demographic model can lead to measurable changes in the predicted growth trajectory.
- Graph of maternity vs. standard length; the two points are actual lengths; looked at 5 trajectories based on a range of maternity as a function of size.

- Maternity of RGSM – size classes of age classes 2-4 estimated from progression analysis of Valdez; assuming progressive sequence of increasing maternity with age class (size class).
- Trying to come up with suite of values for fecundity.
- Largely for purpose of setting baseline data for sensitivity model; to get fecundity value assuming S_0 set at 0.0015; set early survivorship value and produced a suite of fecundity values.

Results

- Mean Age-0 survivorship (S_0) set at 0.0015 for all sensitivity analyses (consistent with estimates based on calculations of quarterly CPUE estimates with high uncertainty in spring quarter during spawning event).
- Estimate of S_0 combined with suite of maternity values to derive age-specific fecundity values for sensitivity analysis.
- Mean Age-1 survivorship (S_1) initialized with alternative values to produce two life tables with different demographic behavior:
  - $S_1 = 0.007$ (from original Remshardt) yields $\lambda = 1.0025$
  - $S_1 = 0.039$ (new estimate from Valdez calculation) yields $\lambda = 1.0681$
  - For each base *S*1 value above, a progressive series of increasing survivorship values was developed with the same proportional increases as set for the maternity values (1x – 3x, by 0.5x).
- Results of sensitivity analysis – with $\lambda = 1.0025$
  - Under conditions of very low baseline pop grown, addition of older classes to demographic analysis results in negligible changes in pop growth potential – even when fecundity of older fish is high
  - Survivorship to older age classes is too low to produce meaningful numbers of older individuals.
- Results of sensitivity analysis – with $\lambda = 1.0681$
  - When baseline population growth is more robust, addition of older age classes results in marked increase in population growth potential – even when fecundity of older fish is high
  - Synergy b/t survivorship and fecundity yields non-linear effects in older age classes
- Essentially shows an increase of approximately 7% per year compared to negligible increase in population growth compared to graph using $\lambda = 1.0025$

<u>Conclusions</u>

- As expected, adding age classes to the RAMAS population demographic model can lead to measurable changes in the predicted growth trajectory. These changes are more pronounced under conditions of relatively higher survivorship and fecundity of individuals transitioning between age classes.
- The outcome of adding age classes is considerably more sensitive to the values chosen for age-specific survivorship.
- Just as ignoring older age classes can lead to an underestimate of silvery minnow population growth potential, ascribing unrealistically high estimates of survivorship and/or fecundity to these older fish can lead to an overestimate of silvery minnow population growth potential.
- How many older fish are out there???

<u>Workgroup Business</u>

MRGESACP video

- The workgroup watched the Program video.
  - 17 minute overview of the Collaborative Program; came out a month ago.

Review action items from March PVA meeting

- Jim Wilber will communicate the PVA-biology request for a map to the Program website to Yvette McKenna
  - **NOT COMPLETED**

- Rich Valdez will send a link to the SWCA library housing genetics studies on the Rio Grande Silvery Minnow (RGSM) to Tetra Tech for posting on the Program website. Tetra Tech will post the link to the website and will send the link to the PVA/Biology workgroup via email.
  - **COMPLETED** - on March 24th by M. Wood
- Dave Gensler will translate the URGWOM output from the pre-ESA water management scenario into ASCII and send to Dr. Goodman.
  - **NOT COMPLETED**
- Dave Gensler will organize an in person meeting between PVA/Biology, PHVA/Hydrology, and Jesse Roach to discuss the possibilities of incorporating use of the longer term, more stochastic monthly time-step model developed by Jesse Roach for use with the PVA.
  - Organize the process in which there will be an exchange of information between the PVA and PHVA workgroups. The intent is to have more communication between the workgroups. It would be a good opportunity to have the PVA modelers and URGWOM modelers in the same room.
  - **NOT COMPLETED**
- Jason Remshardt will forward an email from Rich Valdez containing fish salvage data to Dr. Goodman and Phil Miller.
  - **COMPLETED**
- Jason Remshardt will attempt to locate a FWS study from the mid 1990's that studied large pools in stretches of drying. Jason will send the report to Dr. Goodman, Phil Miller, and to Tetra Tech for posting to the Program website.
  - **NOT COMPLETED**
  - This action item will be completed tomorrow
- Tetra Tech will locate the "Experimental Activities Report" for 2007 on the Program website and email a link to the PVA workgroup.
  - **COMPLETED** - on April 29th by C. Brown Tetra Tech; followed up with Valda to acquire the report
- Rich Valdez will send SWCA data from the "Experimental Activities Report" for 2007 and RiverEyes to Dr. Goodman and Phil Miller so that they may begin to build it into their models.
  - **COMPLETED**
- Rich Valdez will do a modal progression on the 12-24 month and possibly the 24-36 month age classes.
  - **COMPLETED**
- Rich Valdez will send the data he used in the Age and Growth presentation to Dr. Goodman and Phil Miller. Dr. Goodman and Phil Miller will do sensitivity analyses on the data presented in Rich Valdez's Age and Growth presentation.
  - **COMPLETED –** most information was sent, but not all
- Dave Propst will send the papers on the rheotaxic nature of the species to Tetra Tech for posting to the Program website.
  - **COMPLETED –** sent to CP, has not been posted to website since it has been down
- Jim Wilber will follow up with Tom Turner and Megan Osborne about their attendance at the next PVA-Biology meeting.
  - **COMPLETED**

Next Steps

The PVA-Biology workgroup agreed to meet with the BA/BO consultation team and with Jesse Roach to determine what the consultation team needs from PVA in order to move forward.

- **NOT COMPLETED**

Dr. Goodman and Phil Miller will use SWCA data from RiverEyes and the Experimental Activities Report to begin building river drying into their models.

- **NOT COMPLETED** - by Phil Miller or Dr. Goodman

Review/Finalize Past Meeting Minutes

- **Decision:** Group voted meeting minutes will be considered final

Co-Chair Assignments/Announcements

- Dave Campbell – FWS co-chair; David Gensler – MRGCD; no one currently designated from Reclamation

Approve Charter for PVA Biology Ad Hoc Work Group

- The workgroup is going to hold off on approval of the Charter until it is determined whether Reclamation will remain as one of the Federal Co-chairs as originally designated.
- FWS, MRGCD, and Reclamation were initiated as the three co-chairs when the PVA workgroup was originally formed. It was felt that all three agencies should have representatives as co-chairs.
- Dave Campbell will send a formal request to Reclamation requesting a co-chair from Reclamation be appointed to the PVA workgroup and Jeanne Dye will follow up in Reclamation to determine the appropriate staff level for the position.

Approve Annual Work Plan

- A suggested revision of the annual PVA Work Plan was circulated. The workgroup would like to accept the changes from the revision.
- The workgroup will hold off on approval of the Work Plan until after discussion of path forward for both PVA models

<u>*Day Two: Morning*</u>

<u>Developing a path forward for both PVA models</u>

- It was pointed out that the PVA models will be critical in assessing the Biological Assessments (BAs) that will be available at the end of September 2010. The question of what type of product will be available to begin evaluation of the BAs by the end of September was put forward for discussion.
    - It was commented that though both models should be up and functional platforms, that doesn't include modifications that will be made when more data has been collected.
    - It was said that the BO(s) to be developed need to have strong adaptive management components and have the flexibility to accommodate scenarios that will lead to fundamental change.
    - It was mostly agreed that platforms of the PVA models will be available by the end of September but that there will be uncertainties from the parameters as not all data needed is available.
    - There was a brief discussion on the how the PVA workgroup would relate to an adaptive management workgroup. One opinion was that the workgroup would need to be educated more about adaptive management and the composition of the group would have to change. Another opinion was that the PVA workgroup as it stands has a very good understanding of the data, hypotheses, and questions that would contribute to decision processes being as data driven as possible. It was pointed out that the workgroup over time has put together a list of hypotheses that should be tested by the PVA models; it was suggested that the workgroup formalize these hypotheses to become the basis of framework for an adaptive management workgroup.

- The workgroup discussed the key items that should be pursued in order to have the PVA models available by the end of September 2010. A list of "variables to consider" was introduced and put forward for discussion. The list of "variables to consider" was made from a list of questions to be addressed by the PVA that was created at a previous PVA meeting. Copies of the "variables to consider", list of questions, and list of hypotheses were distributed. The workgroup reviewed the "variables to consider" using the list of questions and list of hypotheses for reference. There was general agreement that all of the variables were important and should have placeholders in the PVA models. Workgroup members will review the list of "variables for consideration" in order to remove, expand, and reorganize items. Stacey Kopitsch will send the list of "variables for consideration" to workgroup members for review. It was recognized that finalizing this list of variables does not mean that the list won't evolve.
- The workgroup then discussed research needs and which "variables to consider" should be added to the June agenda for discussion.
    - A request was made that egg drift data be made available. Michael Hatch will make data available from egg monitoring as it relates to water discharge.
    - A request to maintain data momentum was made. The PVA-Biology workgroup requests that all recommendations for data and research needs be forwarded to the Science workgroup (ScW) via the Coordination Committee (CC).
    - One thing that is needed is to determine what survivorship tells us about age classes. This will form the basis of the life structure table.
    - The data that is available for dispersal is tagged fish that were released and records of capture. It was asked if there was additional tagging data available that was not included in population monitoring or estimation. Jeanne Dye will try to find additional tagging data that was not part of population monitoring or estimation.
    - A request was also made as to who does the field work that goes into genetic studies. Jeanne Dye will see if there is information on who specifically does field work data gathering for genetic studies.
    - It was thought that data surrounding demographic responses to hydrologic demographic linkages are of a high priority. There was a brief discussion on using data from salvage records and RiverEyes to quantify drying. It was thought that it may difficult to quantify drying using the available data.
    - Discussions on age specific survivorship, hydrologic demographic response, and egg dispersal will be on the June Agenda.
- There was a brief discussion on the number of age groups that would be represented in each PVA model. It was suggested that each model have 4 age groups of fish; 0, 1, 2, and 3. It was thought that it would not be detrimental to have 4 age groups; the liability would lie in overestimating survivorship in older age groups. There is an age and growth study in progress so putting 4 age classes as placeholders until data from the studies can be filled in would be a good idea. Another opinion was to create a final population stage class which doesn't include age; this is easy to do structurally and a lifespan isn't arbitrarily being created.

<u>Proposed mechanism for integrating hydrologic model output with the RAMAS model</u>

- The workgroup was shown a presentation "*RAMAS Metapop: Testing Management Alternatives*" by Dr. Miller. *For specific details please refer to the presentation.*
    - This is a way to look at available data and make sense out of it.
    - This is taking CPUE data and relating it to hydrological data.
    - This data is looking at overall discharge across the month of May and looking at CPUE measured in July and finding a strong relationship between the two variables.

- We can explore looking at this relationship to try to link hydrologic to demographic variables. Or at least changes in hydrology to changes in demography that would result in an observed change in population density as measured by CPUE. The data set is from 1993 to 2008.
- It's a much smaller dataset with notion to drying; only a few years to look at the amount of impact of drying, identified here as maximum extent of drying. This might be San Acacia, over roughly the period of 2002-2006, looking at maximum extent of drying and then survivorship that could be calculated from July to October. There is some hint of relationship between drying and survivorship.
- May be able to think how you can relate reproductive output of RGSM to variables by considering defining this relationship in terms of fecundity which is related to egg production and survivorship of new individuals to the next census. Remember Dan's been working on parsing annual survivor data into quarterly survivor values. We can look at from the beginning of spawn to next census and look at quarterly survivorship, and see how it can relate with hydrologic measures; at least with spring flow and resulting spawn. I think this looks like a strong and useful relationship.
- Mean discharge and resulting density of fish is the strongest relationship. I would like to look at the monthly time hydrologic model and, after coming up with a mathematical relationship between the two variables described here, use a monthly time step model to develop a sequence of future flows under different scenarios and get a sense of possible flows under different hydrologic scenarios.

- *The following is discussion that occurred after the presentation*
  - There are some loose ends we need to be aware of. Flow doesn't happen a month at a time. The few occasions that jumped out with unusual flow were related to unusual CPUE soon after. We need to be aware of variation of flow within flow as they affect spawning. That bimodality makes a difference. In the course of a month with high flow, the flow crashed; that matters to the fish it seems, possibly in a big way. The episodes in CPUE data with giant CPUE were explained by a concentration of fish in pools. A couple of days of low flow could cause that when the rest of month had higher flows. There's got be a way to turn monthly flows into a probabilistic of what's going to happen day by day. There's a downscaling issue that will need to be addressed if using monthly flows.
  - Your approach is making a jump from hydrology straight to CPUE. When going through the list of demographic issues and variable associated, it's going to end up that you don't have most of the information to do it. Going to have very little real information. That gets back to the discussion, on what you want model to be used for. You may have to take shortcuts or make guesses. Will need to tie back to management wants and what questions will be asked to the model. Egg drift is a big issue on the river and qualitatively could say a statement about it but could not quantitatively.
  - There are 2 themes, what goes into a model and how much a model needs. There was a break through discussion this morning. The science to make models and how the regulatory agency is contemplating using the models to make decisions. We need to have more conversations like that. We can't guess what they are using the models for. The primary goal was to try to create models to allow us to try to get a consensus on the biology of the fish and identify what data gaps are out there to fill them. I got a sense this morning that they may very well be putting the models to pretty serious predictive use.
  - I agree we will find lots of uncertainties when we fill in the parameters. We can't simplify the models to make them go away and we can't legitimately make them go away by making up a number. If there's uncertainty we need to quantify it and that quantification needs to be part of the input and output of the model to give honest reports of results.
    - So if half of the parameters have lots of uncertainty, how do you approach that?

    - That has to be propagated through prediction. There has to be processing of information we have and recognition of information we don't have. It has to be a part of the report to people who will be using results to make decisions.
    - But then you won't end up with output. You will have such large error bars that they are meaningless.
    - Not meaningless, just broad. That's why we are looking at adaptive management. That's a way of coping with uncertainty.
- You cannot use the model to say under this management strategy you will have this number of fish in the river by a certain time. We can't do that in this particular exercise because of the uncertainty. We can say we are most likely to get this result with this amount of uncertainty around this result, then you can develop different management scenarios; if we change this scenario how does it change the result? The description of the response of simulated population becomes comparative and not absolute.
        - The circumstance that it can be legitimately believed with uncertainties is a big technical issue. There's a lot underlying that issue. More than one uncertain parameter becomes difficult.
- What needs to be from hydrologic standpoint is stochastically driven and not deterministically derived flow. Remember there was an issue about the URGWOM daily time model having difficulty dealing with longer time analyses. Length may provide difficulty in understanding long term analysis.
- PHVA is looking at a lot of these topics. We need to get modelers with the technicians and PHVA to discuss things.
- The problem I see with monthly is you lose nuance of how management relates to flow and other nuances. If you go to monthly time steps you lose the nuance of storage and release of water. I think it just misses detail.
- **Question**: How would the monthly time step inform the process if analyses if looking at relation of mean May flows, or peak spring flows, or timing or magnitude of runoff? Will time step analysis help to inform?
    - **Response**: From data, hydrology, and biology standpoint I think it can. There's a choice of how resolution of data is linked to the model structures. Could revise the RAMAS model to be daily, there is the flexibility to change. The lower figure I see as a less uncertain relationship. In other words if the river dries the river dries and it has some relationship to the fish dying. What we don't know is if the fish leave if river dries or if they die.
- I came away from analyzing the data believing a recruitment/spring flow relationship. Summer flow isn't the same as drying. Drying is all kinds of drying. Is drying the loss of continuity, the fish are in pools, and then get reconnection? I'd say the biggest ambiguity in data and interpretation is survival/flow relationship not recruitment/flow relationship. There's strong evidence for spring flow recruitment relationship
- This brings up another issue that we did not identify in the questions; the effect of offsetting dying by artificially creating refugial pools.
- I think this survival/drying relationship discussion could benefit from attention in June.
- The 2 documents, the list of hypotheses and list of questions, I really think they are central to where the process is going and how we communicate what the thinking is to management as part of the future adaptive management process. My recommendation is to incorporate the hypotheses into the questions. Rich Valdez will incorporate the list of hypotheses into the list of questions and send to the workgroup for review

Next Meeting

- The workgroup decided that they're next meeting would be June 29 (all day) and June 30 (morning only), 2010, at the Bureau of Reclamation.

NAME	AFFILIATION	Date 05/04	Date 05/05	PHONE NUMBER	EMAIL ADDRESS
Lori Robertson	FWS	✓	✓	505-761-4710	lori_robertson@fws.gov
Jason Remshardt	FWS	✓	✓	505-342-9900	jason_remshardt@fws.gov
Stacey Kopitsch	FWS	✓	✓	505-761-4737	stacey_kopitsch@fws.gov
David Gensler	MRGCD	✓	✓	505-247-0234	dgensler@mrgcd.com
Wally Murphy	FWS	☐	✓	505-761-4781	wally_murphy@fws.gov
Jeanne Dye	Reclamation	✓	✓	505-462-3564	jdye@usbr.gov
Reese Fullerton	SPO	✓	✓	690-3190	reese.fullerton@state.nm.us
Dr. Daniel Goodman	Specialist – MRGCD rep; PVA Modeler	✓	✓	406-994-3231	goodman@rapid.msu.montana.edu
Phil Miller	CBSG – PVA Modeler	✓	✓	952-997-9802	pmiller@cbsg.org
Nic Medley	NPS – USASO	✓	✓	970-225-3587	carl_medley@nps.gov
Rich Valdez	SWCA/ISC	✓	✓	435-752-9606	valdezra@aol.com
Mick Porter	COE	✓	✓	505-342-3264	michael.d.porter@usace.army.mil
Patrick Redmond	LRPA	✓	✓	505-346-0998	pr@lrpa-usa.com
David Propst	NMDGF	✓	✓	505-476-8103	david.propst@state.nm.us
Andrew Monie	NMDGF	✓	✓	476-8105	Andrew.monie@state.nm.us
Alison Hutson	ISC	✓	✓	841-5201	Alison.hutson@state.nm.us
Scott Durst	FWS	✓	☐	761-4739	scott_durst@fws.gov
David Campbell	FWS - NMESFO	✓	✓	761-4745	david_campbell@fws.gov
Terina Perez	COA	✓	✓	848-7174	tlperez@cabq.gov
Warren Sharp	USBR	✓	✓	462-3637	wsharp@usbr.gov
Mark Brennan	USFWS	✓	✓	761-4756	mark_brennan@fws.gov
Rick Billings	ABCWUA	✓	✓	796-2527	rbillings@abcwua.org
Brian Millsap	FWS	☐	✓	248-6809	brian_a_millsap@fws.gov
Tanya Scott	MRGCD	☐	✓	346-0998	tls@lrpa-use.com
Michael Hatch	SWCA/NMISC	✓	✓	254-1115	mhatch@swca.com
Megan Osborne	UNM	✓	☐	277-4191	mosborne@unm.edu
Tom Turner	UNM	✓	☐	277-7541	turnert@unm.edu
Christine Sanchez	Tetra Tech	✓	✓	881-3188 ext 139	christine.sanchez@tetratech.com
Rachelle Schluep	Tetra Tech	✓	☐	881-3188	rachelle.schluep@tetratech.com

Management of genetic resources in the federally endangered Rio Grande silvery minnow, *Hybognathus amarus*

Thomas F. Turner and Megan J. Osborne

THE UNIVERSITY *of* NEW MEXICO

What is genetic diversity and why is it important?

- Variation in the genome is generated by mutation.
- Genetic drift, selection, population history influence the amount and distribution of diversity.
- Genetic variation can distinguish individuals, populations and species.
- If genetic variation is absent in a population/species, population not be able to adapt to changing conditions, novel pathogens etc.
    - Eg. Tasmania devils-Siddle HV, et al. *(2007) Transmission of a fatal clonal tumour by biting occurs due to depleted MHC diversity in a threatened carnivorous marsupial. Pro Natl Acad Sci USA 104:16221–1622*

Importance of Genetic Monitoring

- Quantifying genetic changes in diversity measures over time.
- Dynamics in the MRG have demographic and genetic consequences for RGSM.
- Genetic monitoring can reveal information that cannot be obtained using traditional monitoring techniques.
- Declines in range and abundance will adversely affect levels of genetic diversity (allelic diversity, increase in inbreeding, reduction in effective population size).
- Long-term genetic monitoring allows the impacts of population decline and of management activities to be assessed.
- May yield insight into basic questions about the relationship of habitat fragmentation, demography and genetics in extinction

Effective Population Size (N_e): size of an ideal population experiencing the same rate of genetic change as the population of interest

- Key parameter in conservation and population biology
- As census size decreases so does N_e
- N_e not census size dictates the rate of loss of genetic variation, fixation of deleterious alleles and inbreeding.
- It is very difficult to estimate N_e from demographic data. N_e can be estimated from genetic data by measuring change in allele frequencies over time.
- Disparities between census size of the population and N_e can reveal processes of interest about the population.
- Here we use VARIANCE N_e (genetic drift in allele frequencies between generations)

Rio Grande silvery minnow - *Hybognathus amarus*

- Dramatically reduced abundance/Geographic Range
- Short generation time
- Pelagic eggs and larvae
- Captive propagation
- Drifting egg recovery
- Refugial populations

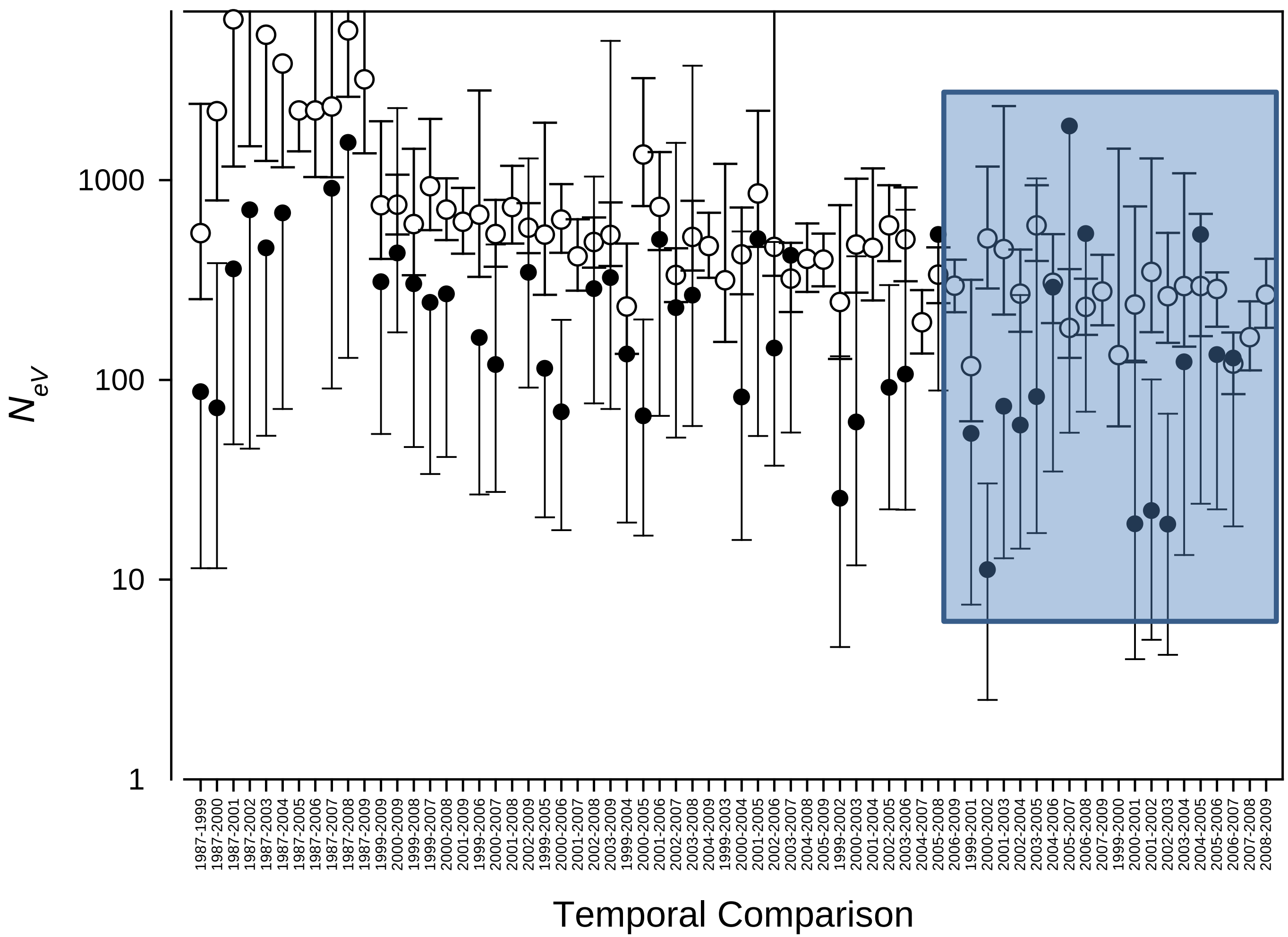
Sampling Design

- Analysed individuals for 10 microsatellite loci and one mtDNA locus.

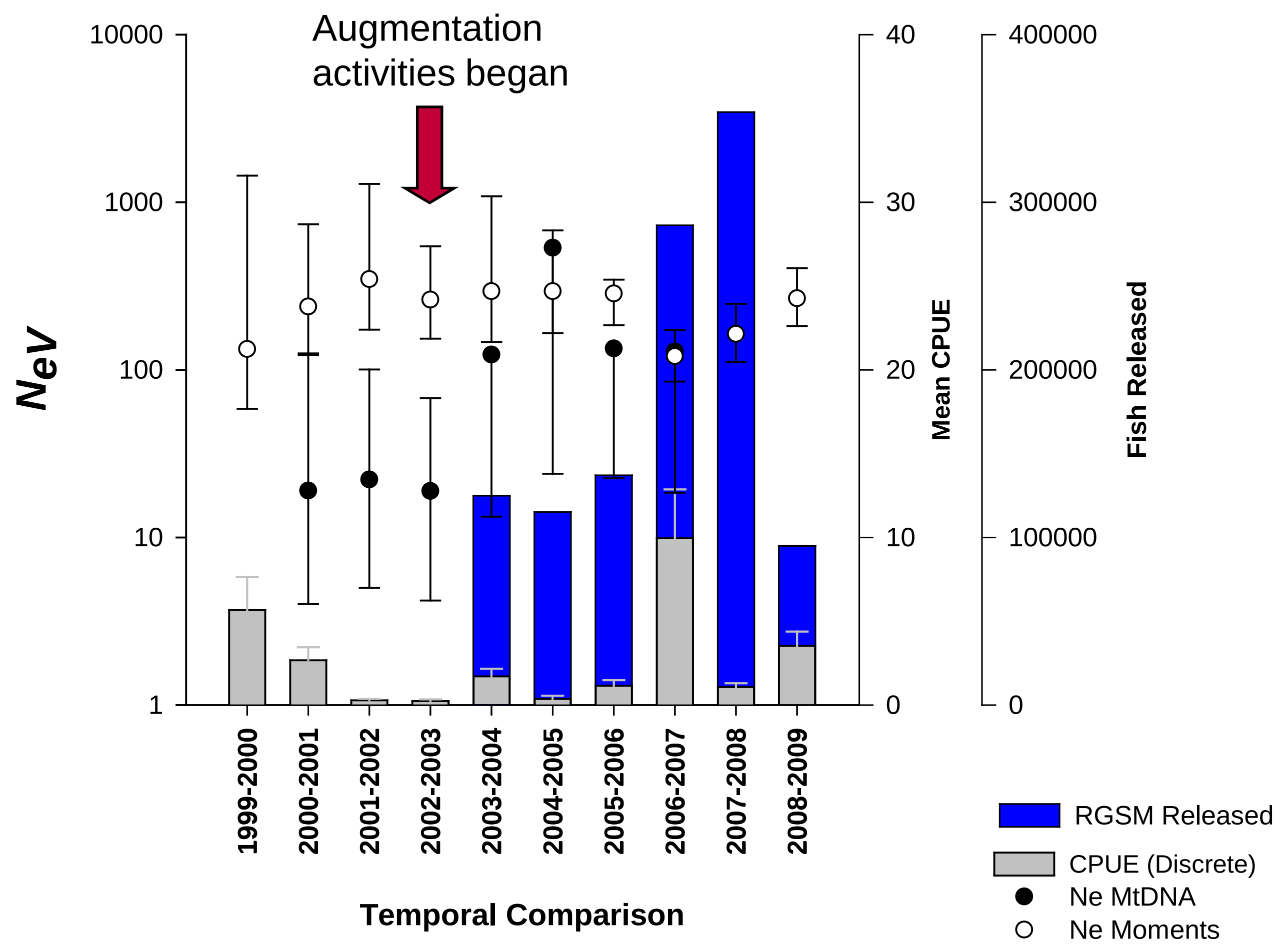
- Adult individuals sampled over 11 generations (1999-2009), and over 10 localities representing the current geographic range of the species.

- Sampling conducted to evaluate temporal genetic diversity and estimate the genetic effective population size to adult census size ratio (N_e/N)

Variance Effective size (N_{eV})



Disconnect between N and N_{eV}



- N_e/N is affected by life history and demographic factors including:
  - Unequal sex ratio
  - Generation time (age at maturation, life span)
  - Population structure (none observed in silvery minnow)
  - Fluctuating adult census size (usually requires $N \leq 10^2$)
  - Variance in reproductive success – $N_e/N \sim 1/V$
    - *Evoked to explain low Ne/N in some pelagic spawning marine species (Hedgecock 1994)*

The interaction of habitat fragmentation and life history for lowering N_e: A viable hypothesis?

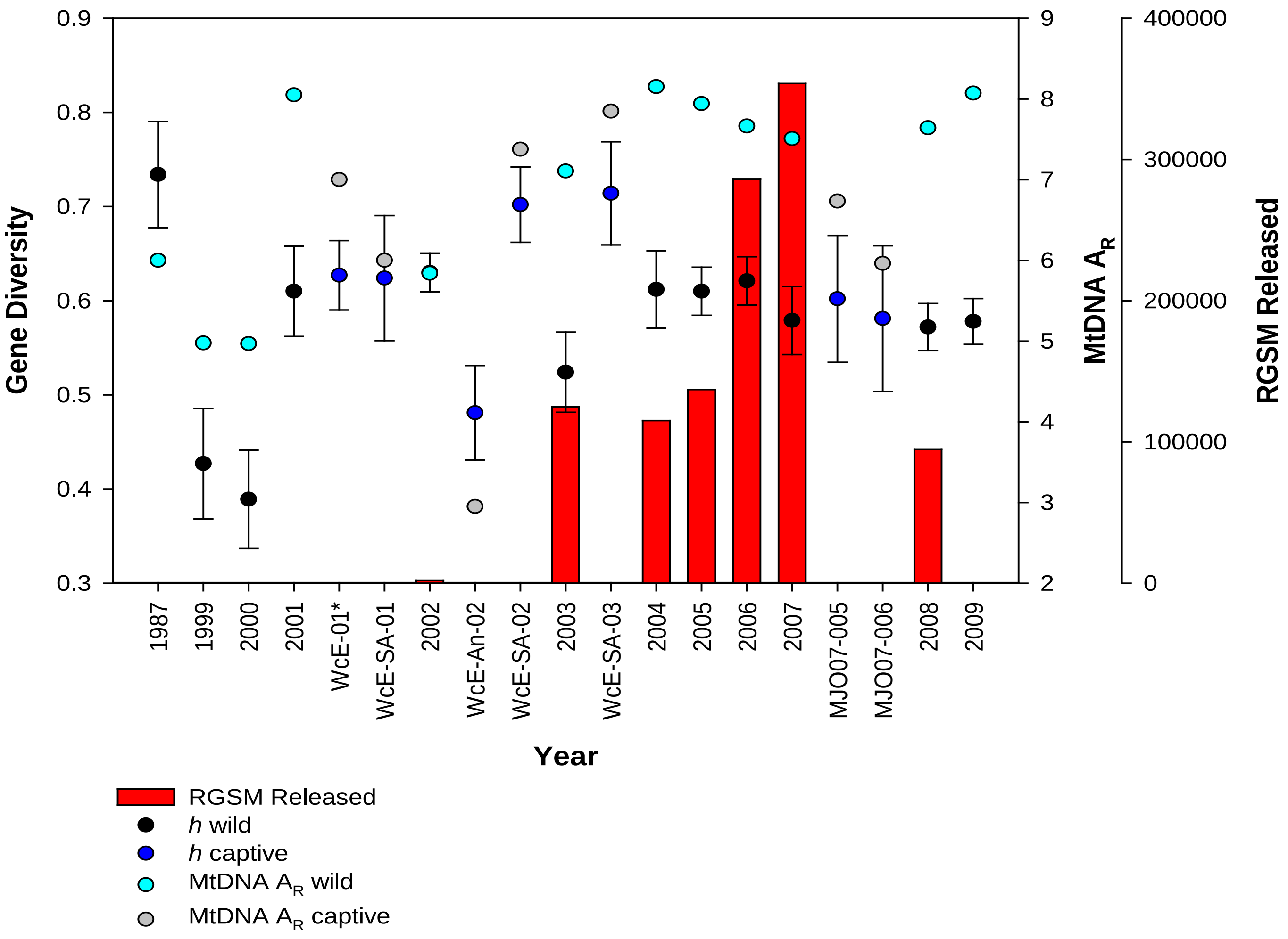
- Present day N_e/N << historical N_e/N (Alò & Turner 2005)
- RGSM eggs drift in genetically discrete groups (Osborne et al. 2005). May reflect spatially discrete spawning aggregations that have differential reproductive success
  - Loss of reproductive output downstream
  - Some aggregations retain production and successfully recruit
  - Many recruits from few breeding individuals
- Ecologically and evolutionarily similar species in unfragmented, but otherwise similar habitats do not show lowered N_e/N (Turner et al. 2006)

Captive Propagation and Rearing

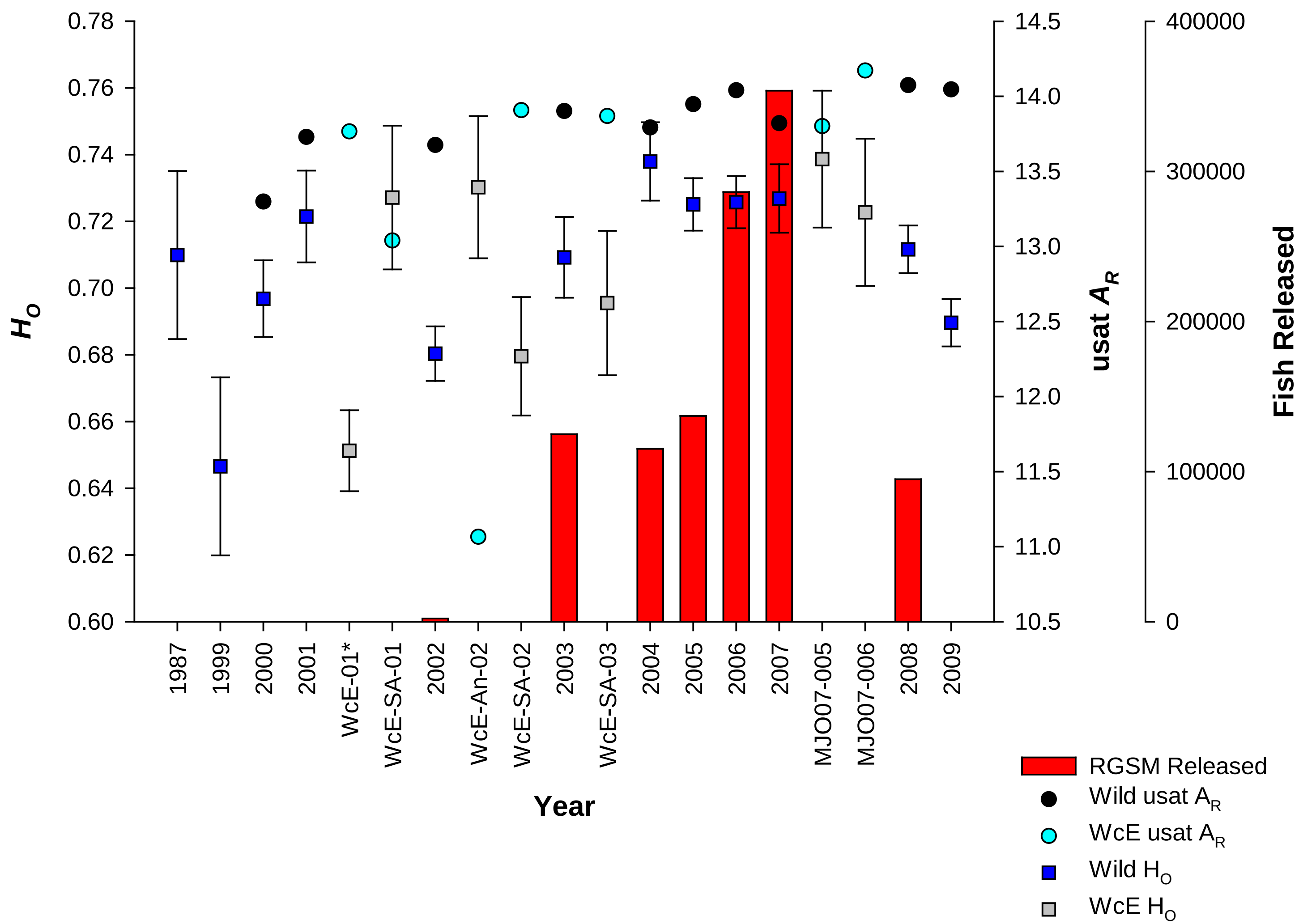
Maintenance of captive broodstock

Rearing wild-caught eggs

Temporal Mt-DNA Diversity



Temporal Microsatellite Diversity



Captive Spawning of RGSM

Small body size imposes limits on spawning techniques

Three experimental approaches:

(1) Pairwise matings

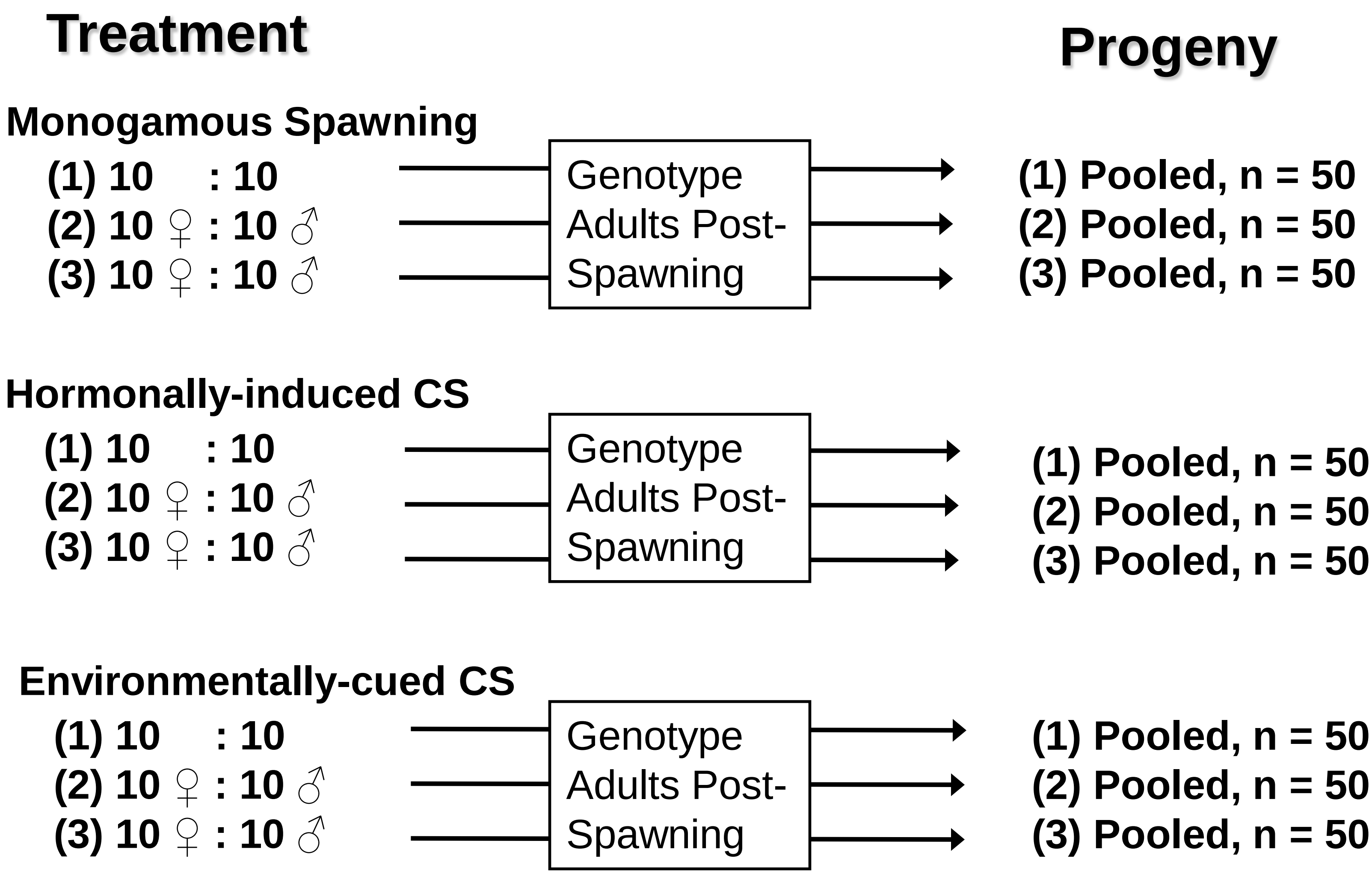
(2) Hormonally-Induced communal spawning

(3) Environmentally-Induced Communal Spawning

Targets:

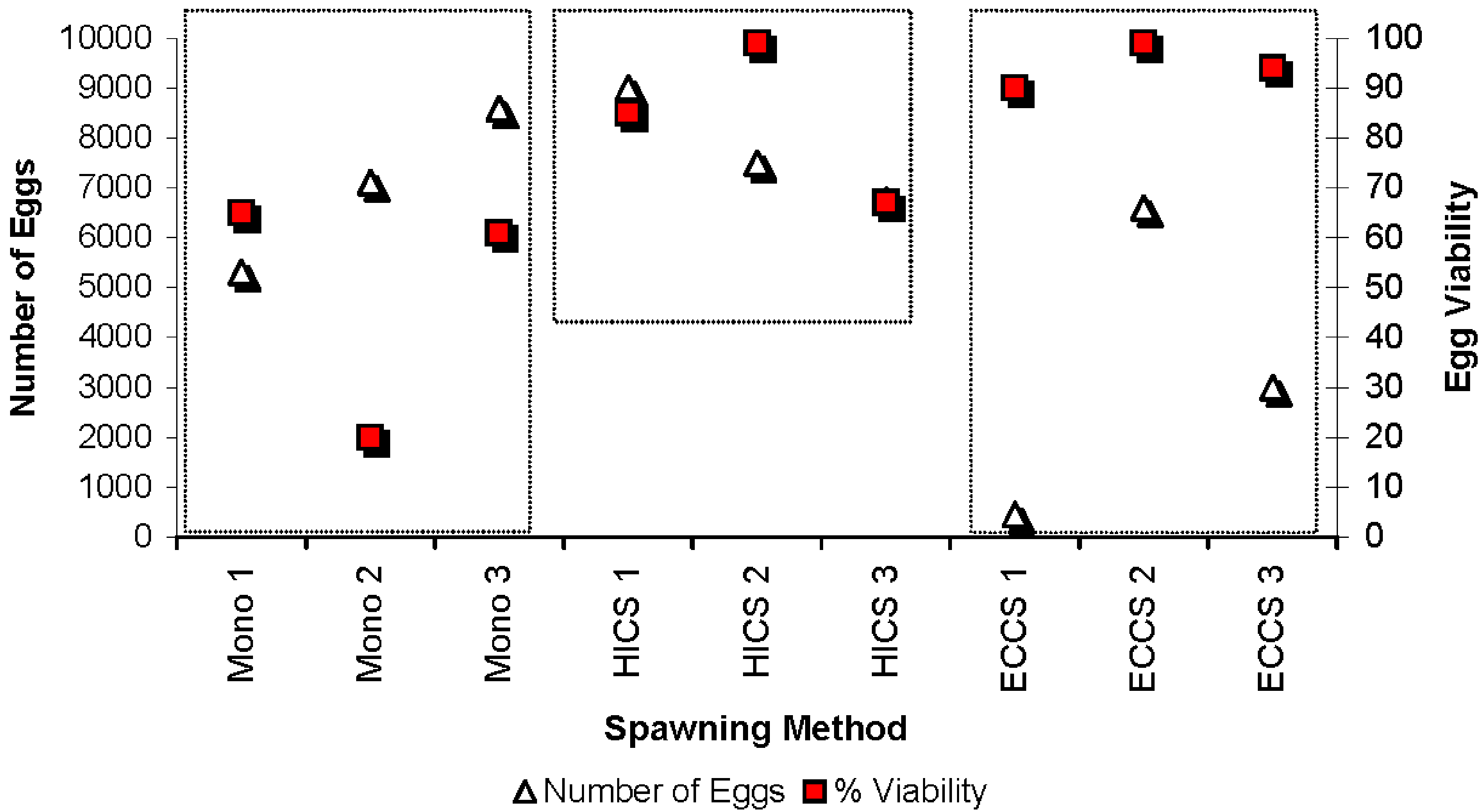
Maximize production and viability; N_e

Minimize loss of diversity; variance family size

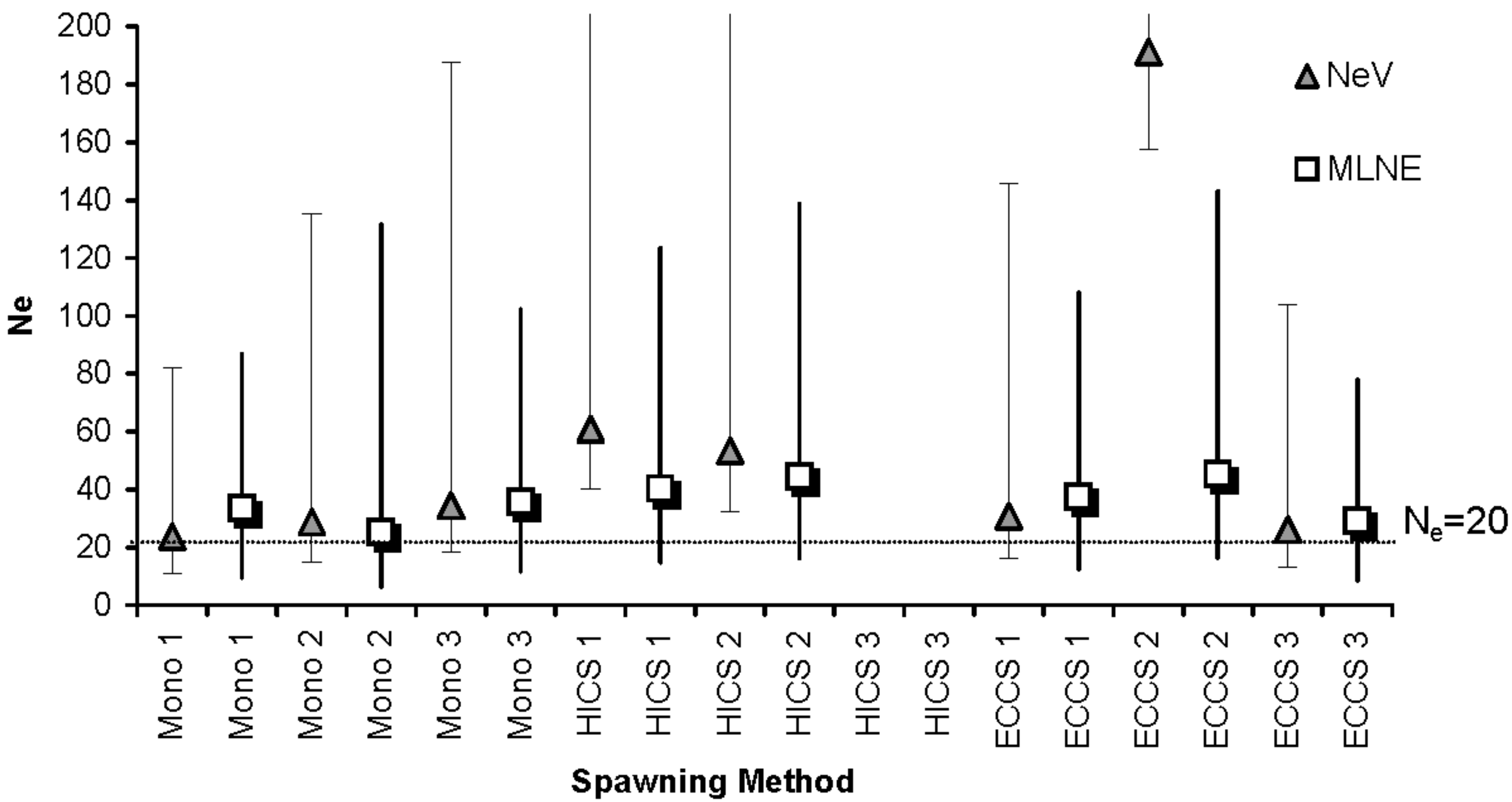


Treatment
Progeny
Monogamous Spawning
(1) 10 : 10
(2) 10 ♀ : 10 ♂
(3) 10 ♀ : 10 ♂
Genotype Adults Post-Spawning
(1) Pooled, n = 50
(2) Pooled, n = 50
(3) Pooled, n = 50
Hormonally-induced CS
(1) 10 : 10
(2) 10 ♀ : 10 ♂
(3) 10 ♀ : 10 ♂
Genotype Adults Post-Spawning
(1) Pooled, n = 50
(2) Pooled, n = 50
(3) Pooled, n = 50
Environmentally-cued CS
(1) 10 : 10
(2) 10 ♀ : 10 ♂
(3) 10 ♀ : 10 ♂
Genotype Adults Post-Spawning
(1) Pooled, n = 50
(2) Pooled, n = 50
(3) Pooled, n = 50

Production and Viability of Eggs Captive Spawning Experiment



Variance Effective Size - Progeny



Hormone induced communal spawning maximizes diversity (as measured by N_e)

Conclusions

- Life history and ecology matters!

- An interaction between early life history and habitat fragmentation exerts strong effects on the trajectory of genetic diversity

- Wild stocks exhibit local spawning aggregations, high variance in reproductive success, and low genetic effective size

- Hormone-induced communal spawning appears to synchronize reproduction and maximize (minimize) target metrics

Conclusions - 2

- Augmentation has increased genetic diversity in wild RGSM stocks but not variance effective size

- Captive propagation and augmentation do not appear to be sufficient to halt long-term declines in genetic diversity; rather, they insure against catastrophic loss.

Rio Grande Silvery Minnow PVA

Longevity Sensitivity Analysis

CONSERVATION BREEDING SPECIALIST GROUP

General Characteristics of PVA

- Original generalized projection matrix structure

	Age 0	Age 1
Age 0	F_0	F_1
Age 1	S_1	0

- F_0 = Fecundity (offspring production) of Age 0 fish

  $F_0 = m_0 S_0$

- F_1 = Fecundity (offspring production) of Age 1 fish
- S_1 = Survival of Age 1 fish, 12 – 24 months
- How does the demographic dynamic change if we add more age classes to this matrix structure?

CONSERVATION BREEDING SPECIALIST GROUP

General Characteristics of PVA

- Expanded generalized projection matrix structure

	Age 0	Age 1	Age 2	Age 3	Age 4
Age 0	F_0	F_1	F_2	F_3	F_4
Age 1	S_1	0	0	0	0
Age 2	0	S_2	0	0	0
Age 3	0	0	S_3	0	0
Age 4	0	0	0	S_4	0

CONSERVATION BREEDING SPECIALIST GROUP

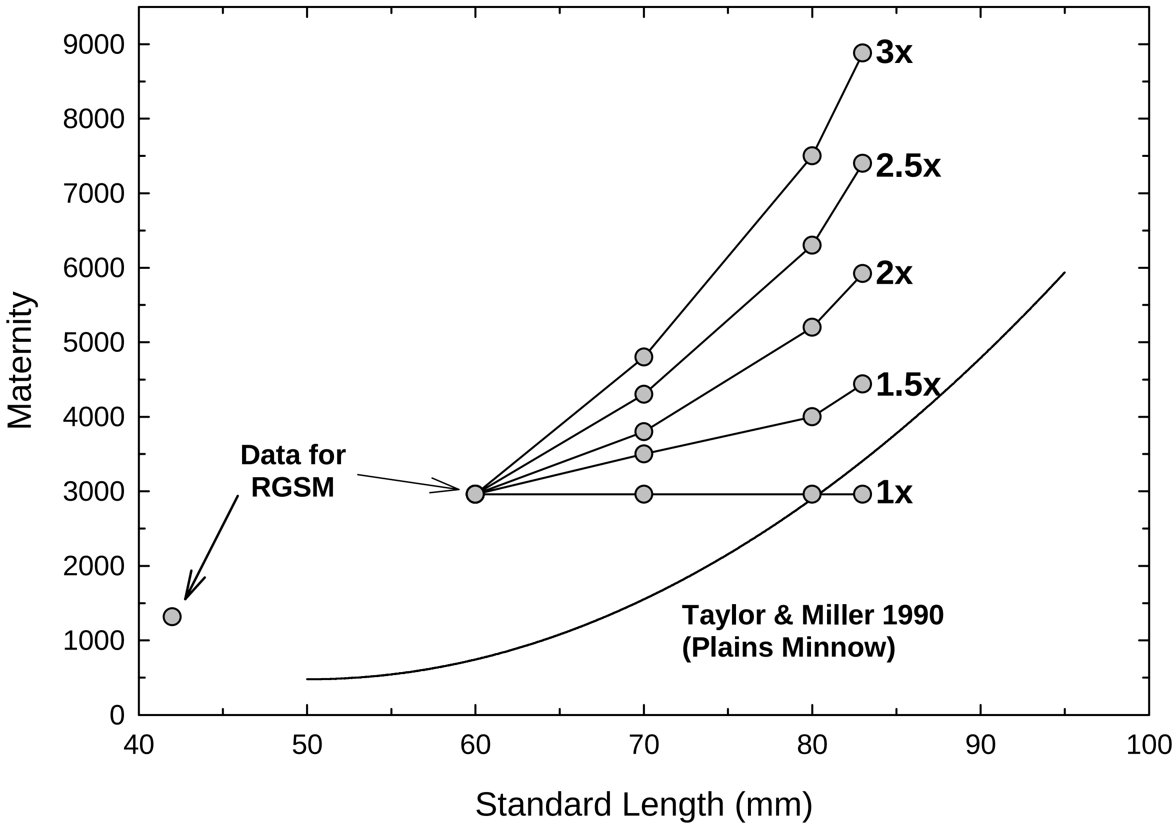
Maternity of Rio Grande Silvery Minnow

- Data on maternity based on the study published by Platania and Altenbach, 1996*
- Total fish spawned in laboratory conditions: 68 (52 Age 0, 16 Age 1)
- Mean maternity
  - Age 0 = 1316 ± 582 eggs (658 ± 291 female)
  - Age 1 = 2961 ± 826 eggs (1480 ± 413 female)
- How do we define maternity of older age classes?

* 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.

Maternity of Rio Grande Silvery Minnow

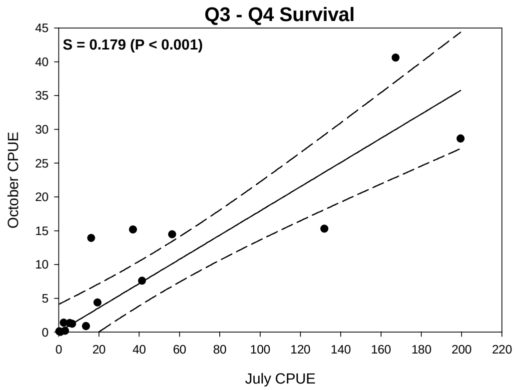
Longevity Sensitivity:
Maternity Scenarios

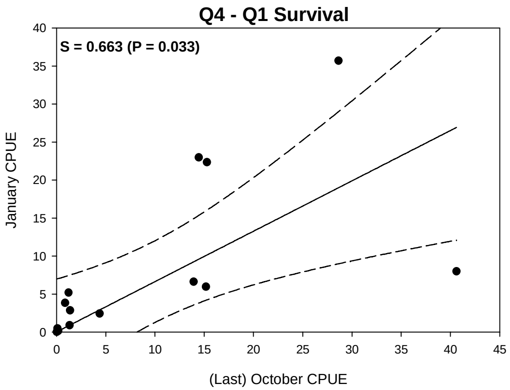


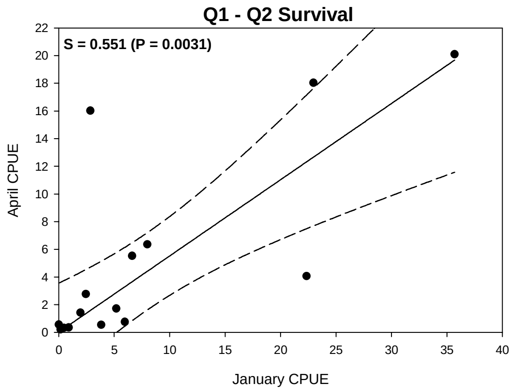
- Size classes for age classes 2 – 4 estimated from model progression analysis of Valdez
- Assume progressive sequence of increasing maternity with age class (size class)

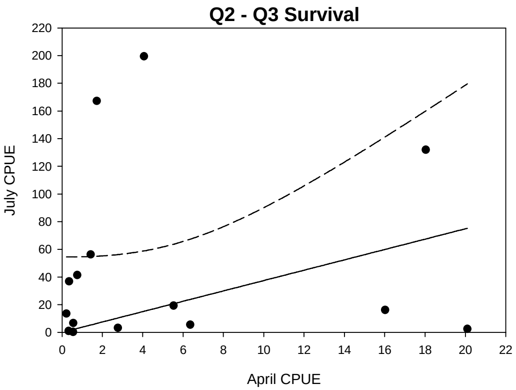
Maternity of Rio Grande Silvery Minnow

- Mean Age-0 survivorship (S_0) set at 0.0015 for all sensitivity analyses (consistent with estimates based on calculations of quarterly CPUE estimates with high uncertainty in spring quarter during spawning event).
- Estimate of S_0 combined with suite of maternity values to derive age-specific fecundity values for sensitivity analysis.









Survivorship of Rio Grande Silvery Minnow

- Mean Age-1 survivorship (S_1) initialized with alternative values to produce two life tables with different demographic behavior:

  S_1 = 0.007 (original Remshardt estimate used in early PVA) → λ = 1.0025

  S_1 = 0.039 (new estimate from Valdez calculation) → λ = 1.0681

- For each base S_1 value above, a progressive series of increasing survivorship values was developed with the same proportional increases as set for the maternity values (1x – 3x, by 0.5x).

Generalized Structure of Sensitivity Analysis

Survivorship S_1 \ Maternity	1x	1.5x	2x	2.5x	3x
1x	A1	A2	A3	A4	A5
1.5x	B1	B2	B3	B4	B5
2x	C1	C2	C3	C4	C5
2.5x	D1	D2	D3	D4	D5
3x	E1	E2	E3	E4	E5

- A total of 25 different scenarios to evaluate
- Output metric: Deterministic growth rate λ

Sensitivity Analysis: Results

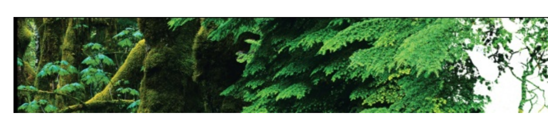
λ_0 = 1.0025

Survivorship S_1 \ Maternity	1x	1.5x	2x	2.5x	3x
1x	1.0026	1.0026	1.0026	1.0027	1.0027
1.5x	1.0027	1.0027	1.0027	1.0027	1.0028
2x	1.0027	1.0028	1.0028	1.0028	1.0029
2.5x	1.0028	1.0028	1.0029	1.0029	1.0029
3x	1.0028	1.0029	1.0030	1.0030	1.0030

Sensitivity Analysis: Results

λ_0 = 1.0681

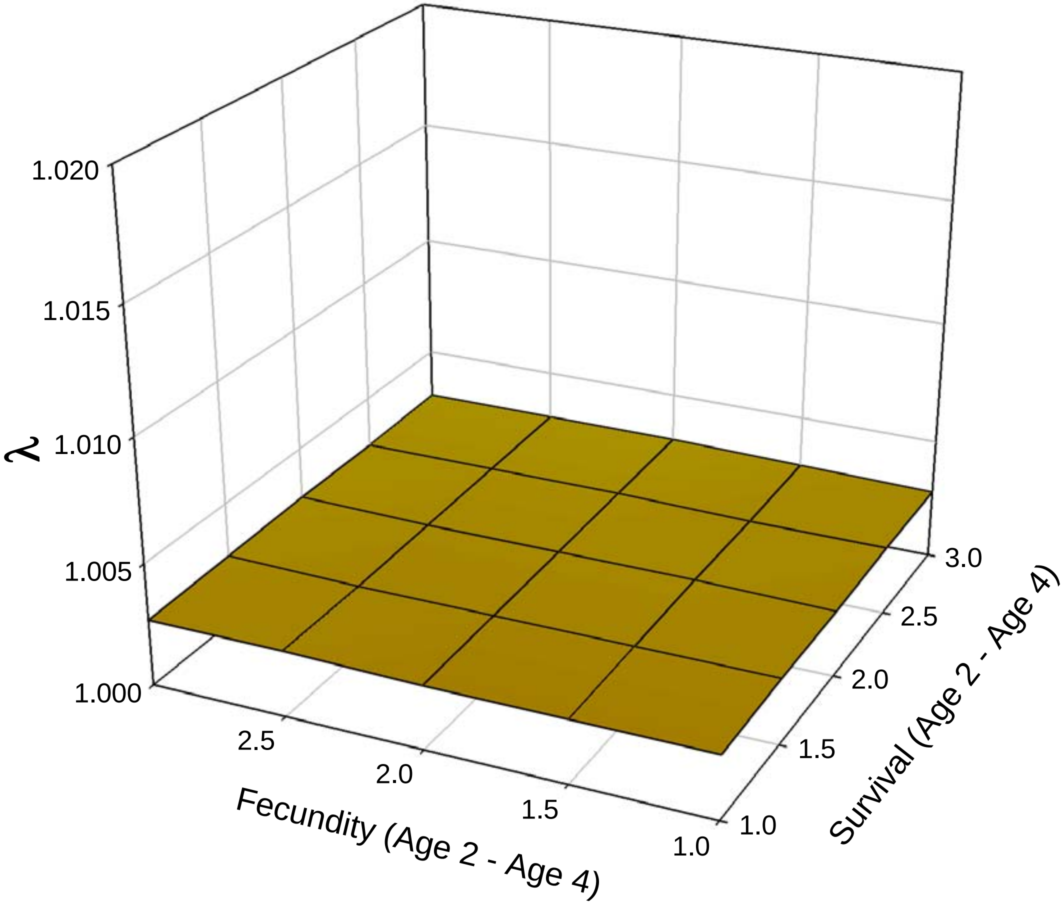
Survivorship S_1 \ Maternity	1x	1.5x	2x	2.5x	3x
1x	1.0709	1.0714	1.0718	1.0722	1.0727
1.5x	1.0724	1.0732	1.0737	1.0745	1.0753
2x	1.0739	1.0761	1.0758	1.0768	1.0779
2.5x	1.0755	1.0770	1.0779	1.0793	1.0807
3x	1.0772	1.0790	1.0802	1.0818	1.0836



CONSERVATION BREEDING SPECIALIST GROUP

Sensitivity Analysis: Results

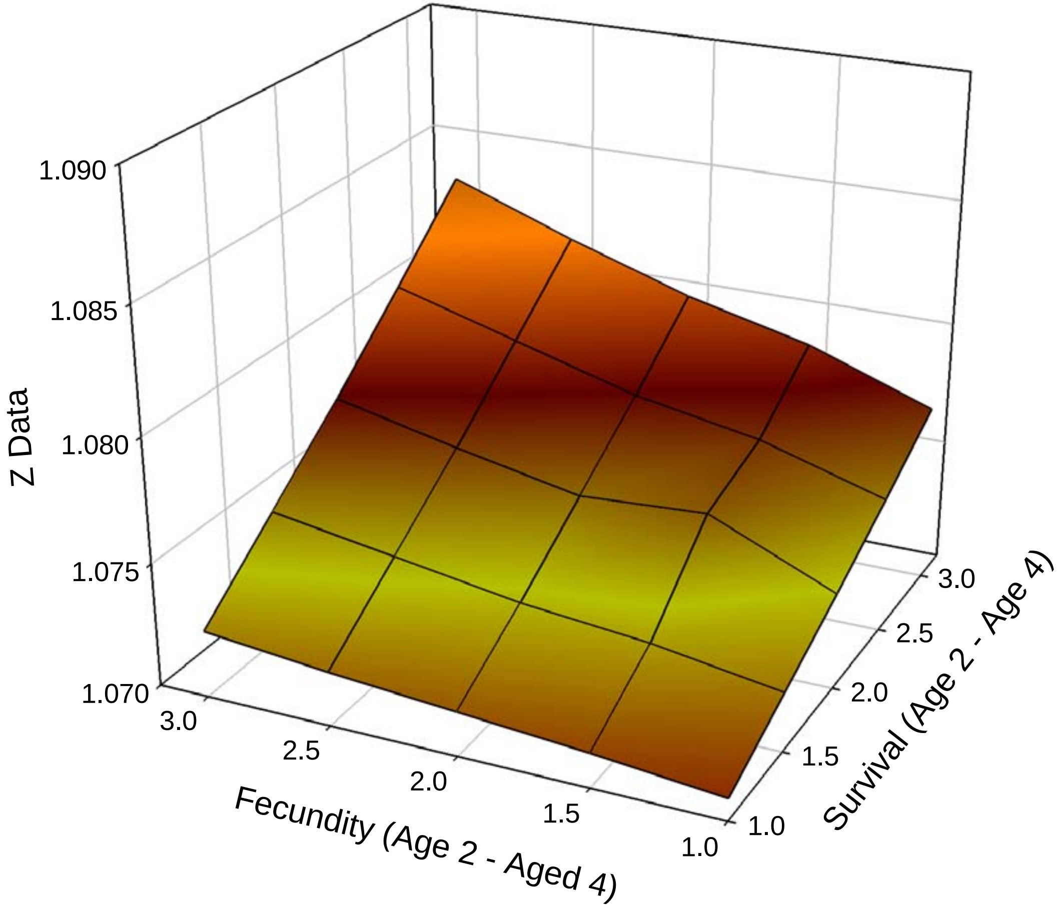
$\lambda_0 = 1.0025$



- Under conditions of very low baseline population growth, addition of older age classes to demographic analysis results in negligible changes in population growth potential – even when fecundity of older fish is high.
- Survivorship to older age classes is too low to produce meaningful numbers of older individuals.

Sensitivity Analysis: Results

λ_0 = 1.0681



- When baseline population growth is more robust, addition of older age classes results in marked increase in population growth potential.
- Synergy between survivorship and fecundity yields non-linear effects in older age classes.

Sensitivity Analysis: Conclusions

- As expected, adding age classes to the RAMAS population demographic model can lead to measurable changes in the predicted growth trajectory. These changes are more pronounced under conditions of relatively higher survivorship and fecundity of individuals transitioning between age classes.
- The outcome of adding age classes is considerably more sensitive to the values chosen for age-specific survivorship.
- Just as ignoring older age classes can lead to an underestimate of silvery minnow population growth potential, ascribing unrealistically high estimates of survivorship and/or fecundity to these older fish can lead to an overestimate of silvery minnow population growth potential.
- **How many of these older fish are out there???**

RAMAS Metapop: Testing Management Alternatives

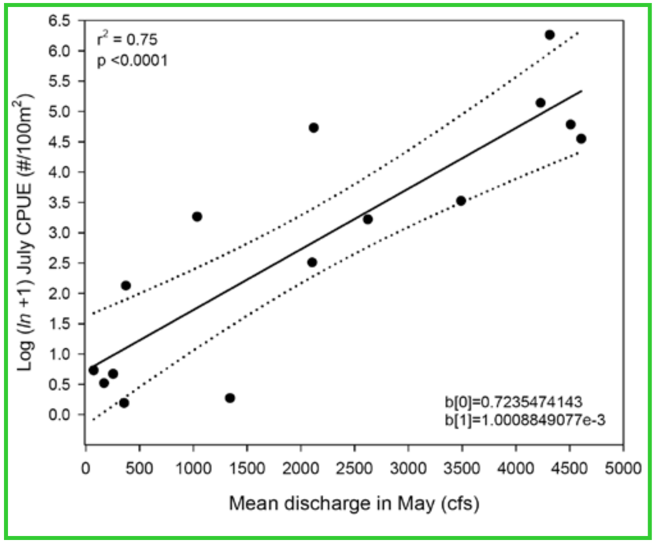
- Of greatest importance to managers is the ability to use PVA technologies to evaluate the impacts of different management alternatives on the predicted future viability of silvery minnow populations in the Middle Rio Grande. These management scenarios will often, but not exclusively, take the form of water management actions. We therefore need to identify the ways in which we can translate specific hydrologic processes into their effects on appropriate aspects of silvery minnow demography.
- To make this association, the primary demographic data available to us are quarterly CPUE. Existing analyses allow us to associate changes in quarterly CPUE with changes in survivorship. Additionally, we associate changes in spring flows and summer drying with changes in quarterly CPUE.

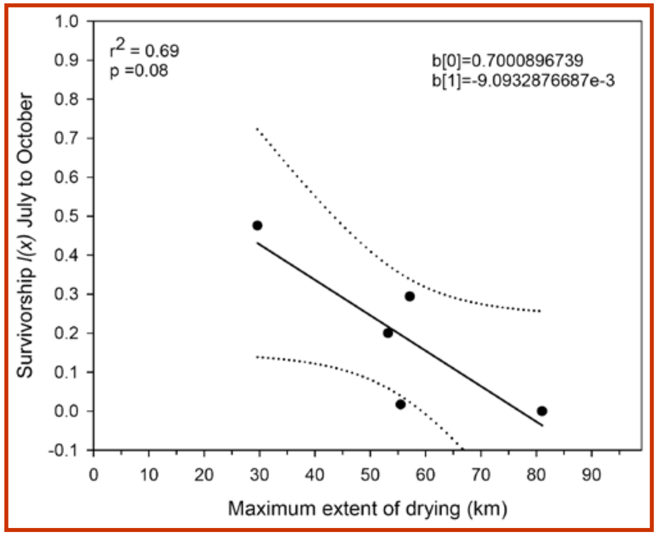
RAMAS Metapop: Testing Management Alternatives

$$F_0 = m_0 S_0$$
$$= m_0 S_a S_b S_c S_d \text{ where}$$

S_a is May – July survival;
S_b is August – October survival;
S_c is November – January survival;
S_d is February – April survival

S_a tied to magnitude of spawning flow
S_b tied to extent of summer drying





RAMAS Metapop: Testing Management Alternatives

Proposed generalized water management strategy evaluation methodology

- Associate average May discharge at given gauge to average July CPUE
- Use flow – CPUE plot to estimate incremental change in CPUE associated with given change in May discharge. Assume given flow-related change in CPUE is determined by corresponding change in survivorship.
- Obtain predicted sets of future May discharge data from hydrology modeling platforms.
- Translate predicted flows to predicted survival values, S_a.
- Use similar protocol to generate sets of predicted summer drying values, using existing drying – survival analyses and hydrology model platforms, to obtain predicted survival values S_b.

RAMAS Metapop: Testing Management Alternatives

Proposed generalized water management strategy evaluation methodology

- Define level of correlation between magnitude of spring flow and maximum extent of summer drying. Assume overwinter survival remains constant throughout analysis.
- Sample from distributions of S_a and S_b created above, constrained by defined correlation, to create set of possible F_0 values corresponding to range of predicted hydrologic variables. Nature of resulting distribution then used to parameterize F_0 mean and variance in model.
- Water management scenarios may be described as simple changes in mean flow or drying that lead to changes in F_0, or could be defined as longer-term trends – as with, perhaps, a global climate change scenario.