Responses from Sturgeon Experts

Dr. Jim Powell

To assure the integrity of the process, it is proper that I not participate in the Expert Review. While qualified, my prior participation in the preparation of the document could be viewed as a conflict.

As one of many contributors to the construction of the PR WSMP, it was my understanding that the WSMP constituted a recovery plan where hatchery augmentation was meant to bolster existing populations while the issues surrounding juvenile recruitment were identified and addressed. In the ranking of Waples and Drake (2004; below) the WSRP was addressing an increase in the rate of sturgeon recovery while addressing the factors that contributed to the decline. Although the emphasis in the WSRP is on augmentation, it was not my belief that it strayed from Conservation Benefits as a motivation for recovering the population. The interpretation from brief wording in the plan regarding future harvest potential places the emphasis of the WSRP on Societal Benefits for fisheries augmentation. To support the former position, conservation genetic practices were written into the plan to embrace a motivation that is conservation based. The harvest perspective ignores the need for a broad-based breeding strategy, instead focussing on biomass production.

Conservation Benefits Items:

1. Contingency against catastrophic loss of natural population
2. Reduce immediate (short-term) risk of extinction
3. Increase rate of recovery
4. Maintain natural population while factors contributing to decline are addressed
5. Reseed vacant habitat
6. Science/experimental contributions to hatchery and/or conservation science

Societal Benefits Items:

1. Legal mandate compliance
2. Fishery augmentation
3. Ecosystem Restoration
4. Public relations/education

In my outside view, the issue is to decide the future of the 'recovery' effort. Is this a Conservation initiative aimed at sturgeon recovery or a Societal initiative based on future harvest?

This is up to the co-managers and the people of WA state to decide.

Waples, R.S. and J. Drake. 2004. Risk-benefit considerations for marine stock enhancement: a Pacific salmon perspective. In K. M. Leber, ed. Stock Enhancement and Sea Ranching: Developments, Pitfalls and Opportunities, pp. 206–306. Blackwell, Oxford.

Dr. Scott Blankenship

General Comments:

I have no conflict of interest. I am working on a white sturgeon project for the USFWS to develop a new population monitoring tool based on genetics metrics, but this is currently in an experimental state and the test population is comprised of hatchery individuals housed in California.

It does not surprise me that there has been deliberation, without resolution, over several months regarding proposed stocking numbers for juvenile White Sturgeon. The problem statement presents two conflicting objectives, with one proposal intending to produce future harvest opportunities and the second proposal intending to supplement the existing population(s) using conservation genetic principles. The project goals, perceived or realized benefits, and tolerance of risk differ depending on the overarching intent of the program(s). The forums will need to resolve the primary intent of the program(s) or the decision-making process will remain unproductive, as supporting a fishery and conserving the genetic diversity of a population segment have conflicting priorities.

The program objectives state that carrying capacity will be determined and supplementation performance will be judged relative to estimated capacity of each reservoir. Yet, there doesn't appear to be a task associated with investigating what might be limiting White Sturgeon populations that currently reside in each reservoir. As a result, the indefinite use of artificial propagation appears to be envisioned, which poses significant challenges (from a genetics perspective) given each reservoir population is isolated (disconnected). A parallel process that identifies limiting factors seems warranted.

Specific Comments:

Proposal #1: 6,500 release

Proposal #2: 4,332 release

1. Based on your understanding of the problem statement, current situation, and proposed releases, what are the pros and cons of each proposal?

Pros and cons depend on the overarching program intent, they are not absolute. The central question is whether these groups are going to be managed based on census size or effective size. If the purpose of the program(s) is to provide a fishery, then reservoirs can be managed based on census size (i.e., the number of fish present). On the other hand, if the genetic trait diversity present in these isolated reservoir groups is a priority, then the effective population size is the metric by which to gauge program performance.

2. Given the status of the white sturgeon populations within the project areas and the goals and objectives of the WSMPs, which proposal do you support and why?

If the primary intent is to establish fisheries in the reservoirs, both proposals have quite similar outcomes from a long-term population genetics perspectives, in that they will essentially replace existing populations with a lower diversity hatchery derived group. Therefore, the proposal that commands the greatest support among all interested parties could be adopted.

If the primary intent is to increase population numbers while not reducing the genetic trait diversity within the groups isolated in each reservoir, then I support neither proposal. Both proposals (as I understand them) will reduce the effective population size below what is likely present now, and subsequently reduce trait diversity maintained within the isolated reservoir groups. Further, each proposal (as I understand them) may result in populations with effective sizes in a range where inbreeding is likely to occur. While the fitness loss expected due to inbreeding is unknown for these White Sturgeon reservoir groups, wild populations in general do not tolerate inbreeding well. For example, an increase in the inbreeding coefficient (i.e., F) from zero to 0.05 is expected to reduce fitness by 26% (Frankham et al. 2014). Given the White Sturgeon groups under consideration are not ESA-listed and are disconnected from the extant larger White Sturgeon gene pool, short-term tolerance of inbreeding is not warranted in order to boost population numbers.

3. Would you recommend a different release number or an alternate stocking rate (fish/area, fish/maternal group, etc.)? If so, why?

If the intent is to create a fishery, I would not recommend an alternative stocking strategy.

If the intent is to increase population numbers while not reducing the genetic trait diversity, I would recommend an alternative stocking strategy, because both proposals (as I understand them) would reduce trait diversity from what is currently present. Alternative stocking scenarios are difficult to evaluate given imprecise biological measures and time constraints for this critique. Yet, I have roughed out some numbers given the modeling parameters already used to develop the current stocking proposals, namely a 10% annual mortality rate, a 30 y.o. age-of-maturity, and a 1:1 sex ratio.

This document states that White Sturgeon population sizes are N<300, N=551, and N=134, for Rocky Reach, Wanapum, and Priest Rapids reservoirs, respectively. If 6,500 juveniles are stocked in Rocky Reach reservoir for five consecutive years (years 1-5), then stopped, it is expected that 1,016 hatchery propagated adults would be present in the reservoir at year 35. Further, if no mortally occurs within the ~300 adults originally present, then the hatchery program will have a contribution rate of 339% (i.e., 1,016/300). If the original ~300 adults suffer mortality over the 35 years, then the hatchery contribution rate would obviously be higher. Using the same logic for the other reservoirs, a 5,000 juvenile and 1,500 juvenile stocking rate will result in 781 and 234 hatchery propagated adults present at year 35 in Wanapum and Priest Rapids reservoirs, respectively. Subsequent hatchery contribution rates would be 142% (i.e., 781/551) and 175% (i.e., 234/134), respectively.

Where this information exercise gets complicated is merging effective size information into the demographic information above. First, let's talk about the reservoir groups. While the effective sizes (N_e) are unknown, a rule-of-thumb is that N_e is ~25% of N, resulting in estimated N_e of 75, 138, and 33 for Rocky Reach, Wanapum, and Priest Rapids reservoirs, respectively. Now, let's talk about the hatchery group. Assuming the individuals in 2013 were all unrelated from each other (with inbreeding coefficients F = 0), the unequal sex ratios will create a hatchery N_e=9.6. Rounding up to 10 to make it easy, let's further assume that for each year (i.e., 5 in this scenario), that the same approximate number of unrelated (and unique) breeders are used for broodstock. This will result in a hatchery population specific N_e =50 (i.e., 10 x 5). Finally, let's talk about the Ryman-Laikre effect, which is genetics theory that relates expected total N_e given a hatchery contribution rate. Given a hatchery N_e =50 and N_e of 75, 138, and 33 for Rocky Reach, Wanapum, and Priest Rapids reservoirs, respectively, contribution rates that do not diminish total N_e can be estimated. The Ryman-Laikre model estimates that total N_e begins to diminish at contribution rates of 0.3 (i.e., 30%), 0.4, and 0.6 for Rocky Reach, Wanapum, and Priest Rapids, respectively (Figure 2). In other words, in order to not lower N_e below current levels, there can be up to 100, 220, and 80 hatchery adults present at year 35 within Rocky Reach, Wanapum, and Priest Rapids, respectively. Note, if the hatchery N_e is lower than assume, contribution rate would need to be lowered to achieve same result.

The same demographic parameters from above can be used to estimate a juvenile stocking rate that would result in the specified number of hatchery adults being present in each reservoir at year 35. Stocking 700 juveniles per year for 5 consecutive years in Rocky Reach reservoir is estimated to produce ~100 adults at year 35. Similar calculations estimate that stocking 1,500 and 500 juveniles per year will result in ~220 and ~80 adults in Wanapum and Priest Rapids reservoirs, respectively. If higher stocking rates are desired, then a hatchery population with greater diversity must be used.

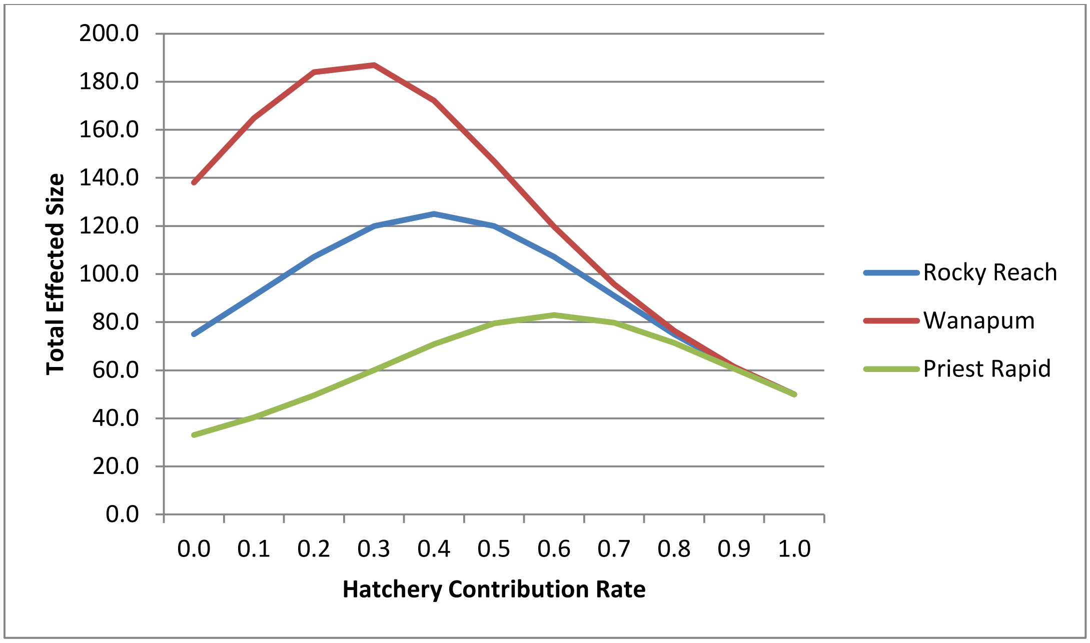

Figure 2. Ryman-laikre models for reservoirs discussed. At zero hatchery contribution, total effective size is that estimated for reservoir groups. At 100% hatchery contribution, total effective size is that estimated for hatchery (N_e = 50).

4. A lot has been said about the potential genetic risks (future genetic bottlenecks) associated with releasing 6,500 juveniles in 2014 based on 12 of the 18 crosses. Given the releases of juveniles into the project areas to date and the potential for entrainment, can you advise the Forums on what you believe would be an acceptable level of risk?

As I understand the programs, there are three genetic risk categories posed by these stocking programs: 1) Reduction of within population genetic diversity; 2) Reduced effective population size; and 3) Domestication selection. There are many strategies for mitigating domestication selection, but this issue is best handled within HGMPs, so I will not deal with that issue here. From a conservation genetics perspective, a minimum threshold for effective size (N_e) that is tolerated in intensively managed populations is N_e=50. At this population size, a majority of trait diversity is expected to be retained over about a 100 year period, although I would expect variation around rate of genetic diversity loss to occur given the complex genetic architecture of White Sturgeon and long generation time. Yet, recent review of empirical evidence suggests that N_e=100 may be a more appropriate threshold for retention of trait diversity in the short-term (i.e., ~5 generations) (Frankham et al. 2014). I would recommend the forums adopt a criteria that reservoir populations must remain above N_e=50 and should remain above N_e=100 over the duration of supplementation evaluation in order to mitigate the risk of fitness loss due to inbreeding. Conservation genetics principles manage to effective size, not census size.

5. If the potential risks become manifest, what is the likelihood that they can be reversed, and if so, how would that be accomplished? Are there examples where this has been achieved?

Effective size functions as a harmonic mean (i.e., 1/Ne). As a result of this property, N_e can decrease quite rapidly (on the order of years). Effective size recovers as a function of the mutation rate, which is on the order of 10s to 100s of thousands of years. Further, the quantitative diversity (i.e., traits) lost within each population would be unknown. Therefore, the best action is to not reduce N_e, as is tends to ratchet lower in finite populations, leaving a smaller gene pool of available trait diversity. The only practical means to increase effective size on a "management" timeframe is to use migration to introduce diversity back into isolated populations. In other words, genetic diversity must be brought in from elsewhere to increase effective size. I am not aware of published documents specific to White Sturgeon regarding donor stock characteristics, but for other listed species (e.g., bull trout) and minimum N_e=500 is recommended in order to be considered as a donor source. I would generally agree with this recommendation.

6. Given the goals and objectives of the two WSMPs, the potential for entrainment, and the low numbers of white sturgeon in the project areas, do you have recommendations for future stocking efforts (e.g., guidance on numbers to release per maternal family or half-sibling family; total numbers to release; age and size at release; use of broodstock, wild larvae, or both; etc.)?

Answered within question #3 above.

Literature Cited:

Frankham, R., C.J.A. Bradshaw, and B.W. Brook. 2014. Genetics in conservation management: Revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. Biological Conservation 170: 56–63.

Dr. Andrea Schreier

1. Based on your understanding of the problem statement, current situation, and proposed releases, what are the pros and cons of each proposal?

The first proposal would increase population size more rapidly assuming that carrying capacity has not been/will not be reached. The first proposal also may allow carrying capacity to be studied sooner. It's not clear to me how the second proposal was developed. I understand the importance of equalizing family sizes to maximize N_e by reducing variance in individual reproductive success (I support that!), but I don't understand why the number to stock from each family can't be derived from the 6,500 release goal. 6,500/12 half sib families = total number of juveniles to stock from each family. The principle of equalizing family size has more to do with increasing genetic diversity preservation and maximizing N_e rather than constraining release sizes.

It would be easier to evaluate pros and cons if survival rate was known. If survival is low, then stocking 2,168 fish may not make much difference.

2. Given the status of the white sturgeon populations within the project areas and the goals and objectives of the WSMPs, which proposal do you support and why?

I honestly don't think there is much difference between the proposals from a genetic perspective. If you equalized family sizes in both strategies, the difference in number of juveniles released per family is <200. I don't know enough about the habitat in the project areas to provide an opinion about how a larger stocking number may affect population dynamics. At this point, there doesn't seem to be enough information to evaluate that.

3. Would you recommend a different release number or an alternate stocking rate (fish/area, fish/maternal group, etc.)? If so, why?

I would recommend using as many wild broodstock as possible each year to maximize the number of maternal groups. (Better yet, use wild captured larvae!) That advice isn't exactly relevant to the two proposals but as a geneticist I recommend focusing more on representing as many parents as possible rather than worrying about differences in release sizes when the total number of fish to be released is so small (relative to many other hatchery programs).

4. A lot has been said about the potential genetic risks (future genetic bottlenecks) associated with releasing 6,500 juveniles in 2014 based on 12 of the 18 crosses. Given the releases of juveniles into the project areas to date and the potential for entrainment, can you advise the Forums on what you believe would be an acceptable level of risk?

Operating a hatchery program is going to introduce genetic risks. Releasing 4332 fish or 6500 fish will reduce the N_e of the wild population (Ryman Laikre) and potentially introduce maladaptive alleles. The choice to operate a supplementation program (vs not supplementing) is going to have a much greater effect on the wild population than the effect of stocking 6500 or 4332 juveniles. It is a good idea to equalize family sizes, a feature of both proposals. With the mating design available, this is the best way to reduce negative effects on N_e.

If you want to further minimize risk, use wild spawned larvae (excess from UCR program?) as they will represent genetic contributions of a greater number of adults and will be less likely to suffer negative effects from hatchery spawning (spontaneous autopolyploidy, hatchery selection operating at very early life stages).

5. If the potential risks become manifest, what is the likelihood that they can be reversed, and if so, how would that be accomplished? Are there examples where this has been achieved?

If genetic diversity loss and/or reduction in N_e do occur, these can be ameliorated by introducing more genetic diversity. This may be accomplished by translocating adults from adjacent reaches or increasing the number of crosses used in supplementation. I am not sure the proposal for selective harvest mentioned above will be successful. What would be the method of selection? How could an angler discern whether a fish belonged to an overrepresented family or not?

Another point is that we don't know how much inbreeding is going to cause inbreeding depression in polyploid sturgeon. Obviously we want to prioritize maximizing genetic diversity conservation in supplementation programs but we can't predict exactly how genetic diversity loss of various magnitudes will affect the wild population.

6. Given the goals and objectives of the two WSMPs, the potential for entrainment, and the low numbers of white sturgeon in the project areas, do you have recommendations for future stocking efforts (e.g., guidance on numbers to release per maternal family or half-sibling family; total numbers to release; age and size at release; use of broodstock, wild larvae, or both; etc.)?

My #1 recommendation would be to supplement with wild larvae from a geographically proximate reach exhibiting consistent recruitment. Using wild larvae preserves natural mating behavior, reduces the incidence of spontaneous autopolyploidy (which may be occurring in this program if standard artificial spawning techniques are used), and increases the number of wild parents represented. If captive spawning must be used, wild broodstock from the same or adjacent reaches are preferable. Continuing to equalize family sizes is important. I would avoid getting excess larvae from captive broodstock because programs with a small number of broodstock are more likely to be inbred (adults are close relatives) which greatly increases the chance of inbreeding depression in wild population. Wild broodstock are likely unrelated given the relative recentness of habitat fragmentation in the Columbia. I would also continue avoiding use of broodstock from below Bonneville and expand this to include adjacent reaches in the Lower Columbia (Bonneville Reservoir, The Dalles, John Day). Patterns of population structure in the Columbia suggest that white sturgeon occupying the Lower Columbia may not have interbred often with white sturgeon further up in the system.

In terms of age and size at release, reducing length of time in the hatchery is best (reducing length of time individuals exposed to unnatural selection pressures) but this also needs to be weighed with survival rate at various life stages. It is obviously not advantageous to stock juveniles at very small sizes to avoid unnatural selection pressure if survival of small juveniles in the wild is low.

Dr. Schreier offered the following addition information based on a question from the Forums:

During the workshop, participants had a question regarding Dr. Shreier's response to question #6. In her response she stated, "I would also continue avoiding use of broodstock from below Bonneville and expand this to include adjacent reaches in the Lower Columbia (Bonneville Reservoir, The Dalles, John Day)." The Forums asked if she was recommending that we should not collect broodstock (or wild larvae) from the lower Columbia (downstream from John Day Dam)? If so, why?

Dr. Schreier responded, "Population structure in the Columbia-Snake system is rather complex, so your question is a good one. There appears to be one population associated with the downstream-most end of the Columbia and one associated with the Middle Snake. Everything in between seems to be admixed, with the influence of the Middle Snake group decreasing as you sample fish downstream. This is likely a reflection of net downstream gene flow (sturgeon entrain downstream through dams but can't be back upstream, except at The Dalles). That being said, it's probably better to get broodstock or larvae from the Middle or Upper Columbia as these are most similar to the project area. The fish in Dalles and John Day are a somewhat more similar to that Lower Columbia population than to the Mid Columbia. If there is no viable option in the Mid or Upper Columbia, Dalles and John Day would be better options than the Columbia River estuary. I wish we had better genetic markers so I could give you a more clear answer, but we are stuck with interpreting dominant microsatellite data for now."

Mr. Ken Lepla

Given the low numbers of white sturgeon [WS] in the project areas, supplementation to rebuild WS abundance certainly appears warranted, and likely the only alternative that can meet Plan goals. That being said, it appears the primary concern (as well as most of the questions) is specific to population genetics and suspect best addressed by fish geneticists. Unfortunately I am not one and therefore my response is more along lines of some general thoughts. My suggestion to the Fish Forums is to rely on the guidance provided by genetic experts regarding what are appropriate mating schemes, release numbers, stocking rates, etc. and the acceptable levels of risk. I do not have the expertise to provide recommendations. However, because of uncertainty and potential for risk it would seem prudent to be proactive and implement strategies that maintain as much genetic diversity as possible (or managing those actions that decrease diversity) rather than later try to deal with reversing potential negative effects that could manifest.

Given WS abundance in the Project areas are small; it also seems beneficial to consider multiple sources for diversity. As you noted and a population structure analysis of white sturgeon by

Schreier et al. 2013 shows, several downstream reaches in the Columbia, with much larger abundances of WS, were genetically similar to the Project areas. Perhaps brood stock or wild larvae (or both) from these reaches can be incorporated periodically in supplementation strategies, as a means to ensure high levels of diversity in the Project areas, as well as reduce downstream concerns about hatchery introgression from entrainment. The Colville Tribe has demonstrated the benefits of collecting naturally-produced larvae (see Jason McLellan). This novel approach potentially could minimize a lot of the genetic concerns within reach as well as downstream export.

Again, thanks for considering my input, but strongly feel the Fish Forums should seek the advice of fish geneticists for guidance to these questions.

The following comments from Dr. McAdam and Dr. Anders were provided after the workshop.

Dr. Steve McAdam

My apologies, but I just don't have the time to give you a proper answer.

I did briefly look over some of the material when I first got your e-mail. I do agree that the concern you are trying to address is important, but given the difference between two scenarios the consequences of choosing one scenario over the other for a single year might be small (at least for an individual year). The possibility of mitigating any 'error' by selective harvest in future is also an important consideration. Other important considerations I can think of are the extant genetic condition of the population, the low number of breeders (not unique to your situation by any means), expected survival rates, other hatchery effects (release numbers is likely only one of many considerations), future harvest levels....all of these would have affect your decision. While I didn't review your information thoroughly enough to see what information was provided on those points, they would certainly be things I would consider over the long term as release numbers continue to be evaluated.

Dr. Paul Anders

There are so many issues, conditions, and uncertainties involved here that require careful presentation and discussion, and I don't want to over-simplify and be misinterpreted. I had intended to provide additional information, but am only able to provide a short summary today re the above subject.

Re the above subject, I agree with Andrea's assessment of the 2 release number options (6,500 vs. 4,332): "I honestly don't think there is much difference between the proposals from a genetic perspective".

Thus, in the short-term (and assuming that this hatchery program will be operating annually for at least the better part of a sturgeon generation?), I could support either proposal. However, I would initially suggest the larger release strategy during initial program years specifically to reduce the time required to produce the needed empirical post-release survival estimates. This recommendation addresses a specific short-term goal, with no intention of downplaying the importance of any other demographic and genetic goals needed for the program, which the collaborating entities and outside reviewers have spoken to.

This recommendation assumes that: 1) the benefits of quickly establishing relevant post-release survival rates up front will exceed the genetic risks of these actions in the short term, or if not, risks can be compensated for over the life of the program; and 2) use of empirical survival rates from the populations of interest ASAP can reduce future risks that could occur without having those estimates. This recommendation does not suggest that the 6,500 fish release number should be maintained. Rather, survival rates should then be used to adjust future release strategies, along with efforts to maximize genetic benefit (e.g. measured as Ne, genetic contribution/diversity) and minimize genetic risks (inbreeding estimates), to be tracked annually but relevant at the generational time-scale, the time-scale at which many genetic risk/population persistence or viability models operate.

That said, the issue of equalization of family size at release is relevant here. This issue is less controversial when family sizes are not limiting or when they have relatively similar abundances. However, differences in pre-release abundance across families in the hatchery invariably occur. Then debate ensues about whether you should equalize family release numbers down to the smallest family size, which in extreme but not unusual cases can be too low to provide any benefit the population. Thus, an agreed-upon policy regarding equalization of family size at release with adequate resolution is needed if it doesn't already exist.

There are many more issues involved here. However, I am not currently able to address them with the detail they deserve, not due to of any conflicts of interest.. just due to conflicts of time....