Independent Scientific Review Panel
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ISRP webpage

ISRP 2022 Follow-up Review of Master Plan for Project: *Freshwater Mussel Research and Restoration* (#2002-037-00)

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Background

In response to the Northwest Power and Conservation Council's December 13, 2021 request, the ISRP provides a follow-up Step review regarding the Confederated Tribes of the Umatilla Indian Reservation's (CTUIR) project, *Freshwater Mussel Research and Restoration* (#2002-037-00).

This 2022 ISRP review considers the following documents submitted by the CTUIR:

- Cover Letter to Patty O'Toole dated December 10, 2021
- *Master Plan: Freshwater Mussel Conservation, Supplementation, Aquaculture, Restoration, and Research, final version (hereafter 2021 Master Plan)*
- Response document to ISRP 2021 review: *Attachment A-CTUIR Freshwater Mussel Research and Restoration Project response summary table*

The CTUIR's 2021 Master Plan (page 2) describes the project's primary purposes:

> Since 2002, the CTUIR FWMRRP has conducted research designed to clarify the status, biology, and ecology of freshwater mussels, with the overarching goal of using this knowledge to restore self-sustaining populations of freshwater mussels to CTUIR ceded area subbasins in order to reestablish cultural and ecological connections. … This Master Plan outlines a phased approach, emphasizing adaptive management, with the goal of supporting the development of a restoration plan to guide freshwater mussel conservation, supplementation, aquaculture (including artificial propagation), restoration, and research for CTUIR ceded areas. The Master Plan provides a strategic framework for the protection, conservation, and restoration of freshwater mussels, through three priority areas: (A) understanding current and future risks through research; (B) conservation, protection, and monitoring of existing mussel populations; and (C) restoration of impaired or extirpated populations and mussel habitat, and development of adaptive management actions.

This ISRP report represents another review step for this Mussel Project stemming from the 2019 Mainstem and Program Support Project Review and subsequent master plan development. In the 2019 review, the Council recommended that the CTUIR address the ISRP's qualifications[1] on scientific issues needing further clarification (ISRP 2019-2, pages 68-69; also

[1] After the 2019 review, the ISRP began using the term "conditions" rather than "qualifications," but the meaning is the same.

see ISRP 2018-8, pages 69-71). The CTUIR responded to the Council's recommendation and ISRP's qualifications in February 2020. The ISRP found that, although the project had significant implications for both the region and the CTUIR, the responses raised significant concerns and did not satisfy the ISRP's qualifications (ISRP 2020-5). In large part, the concerns resulted from having direct responses postponed until the development of a master plan.

In December 2020, the CTUIR submitted a DRAFT Master Plan and a response to the ISRP's concerns. In 2021, the ISRP reviewed the response and DRAFT Master Plan and requested a response (ISRP 2021-1). The ISRP highlighted numerous positive aspects of the project and found the DRAFT Master Plan to be a major step forward for the Mussel Project, displaying careful thinking about how and why mussels should be propagated to support their restoration in CTUIR ceded lands. However, although the CTUIR Response adequately addressed most of the qualifications from the ISRP 2020-5, ISRP 2019-2, and ISRP 2018-8 reviews, the ISRP recommended that the DRAFT Master Plan be revised to provide critical additional information and to respond to several important elements of the qualifications that were not fully addressed and warranted major revision in the master plan. The ISRP organized the response request under three fundamental project components needed for conservation of existing mussel populations and restoration of populations that have severely declined or been extirpated: 1) monitoring the distribution and abundance of mussels, 2) salvage and translocation of mussels, and 3) artificial propagation and augmentation/reintroduction of mussels.

The CTUIR's response (Attachment A) and our review below are organized by these three fundamental components.

Overall ISRP Recommendation

Meets scientific review criteria (conditional)

The ISRP commends the CTUIR for preparing a revised Master Plan, which is significantly improved over the previous version. This project is among a very few in the western U.S. aimed at conserving and restoring populations of freshwater mussels, which are important to the CTUIR to reestablish cultural and ecological connections, in addition to being an important component of North American aquatic biodiversity.

The ISRP requests that by April 2023 the proponents address the conditions below in a separate document to be submitted for ISRP review focused on these 10 key points, rather than revising the Master Plan. More detail is presented about each point in the following sections. When the ISRP review is complete and the conditions are met, the responses should be included as an addendum to the Master Plan or preferably as a fully revised and updated Master Plan.

Conditions

1. **Priority of status and trend baseline data.** The Master Plan continues to focus largely on propagation of mussels for reintroduction and augmentation but less (and in less detail) on evaluating the status and changes through time of mussels across basins in the ceded territory and changes in mussel abundance at long-term monitoring sites. These latter objectives are critical to the success of the program because they set the "baselines" for status and trends that are essential for evaluating the success of artificial propagation. Therefore, the ISRP requests that the CTUIR consider them equal in priority to propagation and develop an overall strategy that provides a better balance.

2. **Analytical and monitoring methods and designs.** The Master Plan lacks information on the sampling designs, methods, data, and analyses of past assessments of the status and trends in mussel distribution across subbasins and of the density of mussels at long-term monitoring sites. The ISRP requests detailed information on the sampling designs, methods, and analyses of these two key components, and summaries of the data generated. These data are critical for planning conservation and restoration, and for evaluating progress.

Mussels are cryptic, so measuring mussel distribution and abundance requires robust methods that account for imperfect detection (i.e., mussels are present but not detected, creating false absences). The proponents are collaborating with experts to apply methods of sampling and analysis that account for imperfect detection. The ISRP emphasizes that developing these robust methods is critical to ensure that long-term changes in distribution and abundance, and outcomes of restoration, can be measured accurately and with acceptable levels of confidence.

The ISRP requests that the proponents report on the progress of their collaboration on these topics, the methods developed, and how they have been applied in the upcoming 2022 field season. In the sections below the ISRP provides additional details about the need for methods for a) formally estimating occupancy across subbasins, and the relationship of occupancy to habitat features; b) estimating density at monitoring and restoration sites, and c) establishing trends in density through time.

3. **Statistical design and assistance.** The summary of responses in Attachment A (Response, hereafter) and the Master Plan lack information about how the proponents will develop a probabilistic sampling design to select sites for measuring mussel distribution through time in the future. The ISRP requests that they work with a qualified statistician to develop a sampling design that includes spatial and temporal elements, can accommodate constraints of access to private land, and integrate past sampling and data where possible.

4. **Details on eDNA work.** The ISRP commends the proponents for their planned pilot sampling using eDNA to detect mussel presence. This may be useful for broad-scale sampling but may not be suitable for finer-scale detection of mussel presence, depending on the transport and possible degradation of the signal downstream. Further work, and additional details, will be

needed to assess the technique and sampling strategy. The ISRP requests that the proponents provide additional details on the eDNA sampling design, field technique, and laboratory analyses to be employed.

5. **Habitat and water quality variables.** The Response and Master Plan lack specific information on what habitat variables will be measured at sites sampled for occupancy, and at sites selected for monitoring long-term density. These measurements are critical for assessing how habitat influences mussel occupancy and density (i.e., habitat requirements for mussels). Likewise, certain contaminants and water quality constituents may completely prevent mussel survival. The ISRP asks that proponents specify what habitat and water quality characteristics will be measured, including the methods used, and urges them to work with the USEPA and other agencies to assess which stream segments will be suitable vs. unsuitable for mussel restoration based on water quality and contaminants, or their surrogates.

6. **Salvage and translocation.** The Master Plan discounts the opportunities to salvage mussels, even though hundreds to thousands of mussels are apparently available for translocation or for sampling to estimate detection probability. The ISRP requests that the proponents address how, with advanced planning, these mussels can be used to a) document the biological and genetic characteristics of mussels used for translocations, b) formally test the survival of salvaged mussels used in translocations or to augment populations, and c) formally estimate detection probability of different size classes of mussels at the surface and buried beneath the surface. Although survival of translocated salvaged mussels may be modest (e.g., 40%; Carey et al. 2015), the large number of mussels potentially available makes this option attractive. Likewise, given advanced planning, such salvage operations provide a golden opportunity to estimate detection probabilities for different size classes of mussels at the surface and buried beneath it.

7. **Justification for 500 adult production objective.** The Response and Master Plan lack information, and justification, to support the quantitative objective of producing 500 adult mussels for outplanting. The ISRP requests that the proponents work with regional experts to develop a simple viability model that includes both demographic and genetic considerations to estimate the number of adults needed for their propagation and restoration goals.

8. **Host fish distribution and abundance.** The ISRP urges the proponents to develop a landscape-level analysis of the known distribution and relative abundance of host fishes, a critical uncertainty for planning translocations and restoration to eventually establish sustainable populations (see Modest et al. 2018). The project could develop this analysis using existing data from the CTUIR and regional agencies. The project could also generate information on distributions of host fish species using its eDNA sampling for mussels and obtaining eDNA libraries for the fish species in the region from cooperating state and federal agencies.

9. **Building redundancy to manage risk.** The ISRP strongly urges the CTUIR to develop protocols to prevent loss of a major portion of their program if a catastrophe strikes. Building redundancy into operating systems is a fundamental requirement to buffer against such losses.

10. **Advisory group.** As indicated above, this project is among a very few in the western U.S. aimed at conserving and restoring populations of freshwater mussels, and it is developing complex experimental programs for propagation, salvage and translocation, and assessment of status and trends. To augment the project team's expertise in mussel biology, the ISRP urges the proponents to establish a formal advisory group of four to five additional experts in mussel biology and ecology, artificial propagation, restoration, and statistical sampling design and analyses. These may include the experts with whom the proponents are already working, as well as others, to ensure expertise in the broad array of topics required. The ISRP suggests that the advisory group meet annually, especially during the next several years, and their recommendations should be included in the project's annual reports. This group could play an important role in the adaptive management process for the project.

ISRP Comments on CTUIR's Responses to Previous ISRP Review

Below is additional detail to help the proponents understand each of the 10 conditions above. The ISRP requests that the proponents carefully consider these fuller explanations and address the additional details in their responses to the 10 conditions above.

I. Monitoring the distribution and abundance of mussels

The Draft Master Plan contains much information requested in previous ISRP reviews, but several critical components remain incomplete or lack details about next steps.

In particular, a fundamental component of the Master Plan should be a clear explanation of the past assessments of status and trends of mussels within the CTUIR reservation and ceded lands, with detailed information on assessments completed in the five subbasins—Umatilla, North and Middle Fork John Day, Walla Walla, Grande Ronde, and Tucannon. The ISRP also requests clarification on whether the proponents plan to conduct surveys in the Touchet, Powder, and parts of the Malheur river basins that are within the boundaries of the ceded lands.

Distribution of mussels in subbasins – The maps showing presence and absence of mussels for each subbasin are a welcome improvement but do not indicate changes through time. The proponents report an initial survey of mussel distribution in 2003 in the Umatilla and John Day rivers, and surveys in new basins or resurveys in future years. As well, it is unclear how these sampling locations were chosen (e.g., opportunistically or based on a sampling design) and when, where, and how frequently locations were sampled to produce the distribution maps in Figs. 4.2-4.7.

To make this clear, the ISRP requests that the proponents 1) describe the sampling design used to select sites, and 2) prepare a set of tables of the data on mussel density (or presence, if these were the data recorded) by species for each site sampled on each date, and also indicate the sampling method used (e.g., snorkeling timed search, snorkeling transect). If there are useful ways to further summarize these data in the maps, for example by distinguishing sites where a mussel species was originally present but has not been collected in the last decade, this would also be useful.

Density of mussels at long-term monitoring sites - the Master Plan reports that multiple long-term monitoring (LTM) sites were established between 2008 and 2018 in the Umatilla, John Day, and Tucannon subbasins (note that the Master Plan cites 2009 to 2013 in other parts of the text), but these data are not presented.

The ISRP requests information on 1) the method used to select the LTM sites, whether opportunistic or based on a sampling design, 2) their locations on the maps, 3) methods used to detect and count mussels, 4) graphs or tables showing the density of mussels detected for each site by sampling date, and 5) any analysis of trends through time, such as by regression or time-series analysis. The proponents should conclude by summarizing these trends by subbasin in their narrative.

A. Measuring mussel distributions across ceded subbasins

1. *Probabilistic sampling design for assessing the true distribution (i.e., presence/absence) of mussels*

The proponents report that they conduct annual surveys of mussel distribution and LTM sites, but it is unclear from the Master Plan exactly where, when, and how this is done. Estimating the distribution of mussel species across subbasins requires a sampling design that allows extrapolating to unsampled reaches. This is likely to require stratifying stream segments by channel or valley characteristics that control mussel distribution and then applying a probabilistic sampling design (such as a GRTTS design) to select sampling locations within strata to allow unbiased estimates of mussel presence throughout subbasins.

The proponents report that they will conduct a pilot study using eDNA, but this does not address the need to select locations for regular sampling based on a predetermined design. The ISRP understands that access for sampling is not permitted in many locations because of private lands. Nevertheless, the proponents are asked to work with a qualified statistician to develop a suitable “hybrid” stratified sampling design that accounts for this constraint, as well as a plan for repeated sampling of sites through time. Such a design also may be able to include some sites sampled previously, to capitalize on past data.

The ISRP understands that this new sampling design will need to be phased in through time, perhaps by working through each subbasin in turn.

2. Method for detecting the presence/absence of mussels at each sample site

Once sites are selected for sampling, a critical uncertainty that must be addressed before data are collected is to develop a method to accurately measure mussel presence or absence. In their response (Attachment A) the proponents report that a variety of methods will be used, but for none of them is the accuracy known.

The proponents report a low detection rate for juvenile mussels owing to small size or deep burrowing behavior (p. 23), and even larger mussels may be difficult to detect. This is corroborated by other researchers, such as Wisniewski et al. (2014) who reported that, on average, mussel species present at sites in a Georgia river were detected only 25% of the time by snorkeling one 1 X 10-m transect. In contrast, snorkeling 10 transects increased this probability of detecting species at a site to >95% for nearly all but the rarest of the 19 species. Conducting this kind of sampling and coupling it with formal occupancy modeling allows quantitatively estimating "false absences," and ultimately, the distribution status of mussels across sites within subbasins. The proponents report starting a preliminary occupancy modeling effort using available data, but no details are provided.

The proponents report that in 2022 they will conduct a pilot study in one basin using eDNA to detect mussel presence/absence (p. 59), and also plan to use eDNA to select supplementation sites (Table 5-2). For example, using eDNA was an advantage for a broad survey of mussels in Wyoming (Wilmot et al. 2019). However, because eDNA flows downstream the ISRP anticipates substantial preliminary testing will be required to understand how the eDNA signal decays with distance (see references cited in Wacker et al. 2019), and hence how useful eDNA will be for detecting mussels at a site scale vs. a whole-basin scale. For example, eDNA sampling may be useful for broad surveys to determine whether any mussels are present in long segments of a river not previously surveyed (e.g., the Powder River) but less useful in detecting presence at specific sites over time in a well-surveyed river basin. Detection probabilities can also depend on the size of local mussel aggregations, with diminishing detection probabilities for smaller aggregations (Wacker et al. 2019). If decisions about supplementation are based on abundance of mussels, then it is unclear how useful eDNA will be for this purpose.

The ISRP also requests more information about who will be conducting the eDNA analysis, once the samples are collected. In addition, eDNA will be useful for detecting the presence of host fishes, if an appropriate eDNA library is developed.

If eDNA is found to be accurate at a site scale, then it could be used as a "gold standard" against which to measure site-level detection probability of other methods, such as snorkeling to detect mussels along transects.

3. Habitat variables important to mussels that will be measured at each site

The proponents report basic habitat requirements for mussels, including stable substrate (few fines) and gradient <3%, and include a decision framework based on an unpublished study (Figure 4-8). This work provides useful guidance for the macrohabitats and mesohabitats most suitable for the three mussel genera. At the microhabitat scale, mussels appear to be habitat generalists, within broad limits encompassed by this framework. The ISRP urges the proponents to publish the results of this research in the refereed literature.

Although the proponents report using long-term data to assess habitat suitability (p. 61) and measuring four broad categories of habitat data (hydrogeomorphic, biotic, water quality, and human impact, evaluated at the channel unit and reach scale), the Master Plan does not specify relevant habitat variables important to mussels that will be measured at each site. The ISRP requests a list of specific variables that will be measured, and a basic description of the methods used to measure each. For example, if substrate is to be measured (an important habitat characteristic for mussels), will it be by sieving substrate samples, a Wolman pebble count, estimating embeddedness, or what methods? What water quality parameters will be measured? Do habitat measurements include adjacent riparian and floodplain characteristics? The protocol for measuring habitat, and the variables to be included, should also be entered into MonitoringMethods.org.

In Section 6.4.9, the proponents indicate that contaminants and water quality may limit restoration of mussels. In Section 5.8.3.1, they report that survival of outplanted juveniles in research vessels will provide a bioassay of whether factors like water quality and contaminants limit mussel restoration. The ISRP urges the proponents to work with partners from the EPA and other agencies that monitor contaminants to assess in advance (if possible) which stream segments are likely unsuitable for mussel restoration owing to water quality limits, thereby avoiding wasted efforts.

4. Plan for fitting formal occupancy models to the data gathered

The response and Master Plan state that "a preliminary occupancy modeling effort has been initiated using long-term monitoring and survey data collected by the CTUIR FWMRRP" but provide no further information. The proponents indicate that Dr. Jim Peterson (Oregon State University) and Dr. Jeanette Howard (The Nature Conservancy – former mussel project leader for CTUIR) will model habitat associations, but the proponents provide no detail about the specific responsibilities and tasks. The ISRP asks that a more substantive description of the goals, tasks, and timeline for this collaboration be provided.

A formal occupancy model can also integrate past and future habitat data, allowing a robust evaluation of the habitat variables that account for distributions. The ISRP requests that the proponents work with Drs. Peterson and Howard to explore whether this type of analysis would

be beneficial or not, based on current or future data.

B. Measuring mussel density at long-term monitoring sites

1. Sampling method for estimating density of specific size classes of mussels

Estimating density at long-term monitoring sites, and after transplanting or augmenting mussels, requires a different method than the occupancy models described above. In Table 5-2 proponents list Line Transect, Random Quadrat, and Mark-and-Recapture as three methods they will use to estimate density for these purposes. However, only Mark-and-Recapture can provide an estimate of true density of mussels, and then only for those mussels on the surface that are available for mark-and-recapture (i.e., not for subsurface mussels). The other methods measure relative abundance and cannot address the potential bias in these estimates.

The proponents report that population estimates (i.e., estimates of true density and abundance) are possible only during salvage efforts (p. 49). However, these salvage efforts should be used to measure the probability of detecting individual mussels of specific size classes (e.g., juveniles, small adults, large adults), both on the surface and in the subsurface sediments. For example, it might be found that only 60% of large adult mussels actually present on the streambed surface in a quadrat (as determined by excavation) are detected by snorkelers. These detection probabilities may also vary with stream depth or other characteristics. If these can be modeled based on a series of tests over a range of conditions, then they could be used to expand future counts and provide more robust estimates of abundance.

The ISRP recently learned of investigators in Wyoming and Nebraska who marked mussels by gluing PIT tags on their shells. This allowed locating mussels on future surveys with backpack PIT-tag detectors, including mussels buried beneath the surface. The ISRP urges the proponents to contact these investigators and explore this method for estimating mussel density; the lead biologist in Wyoming is Stephen Siddons (stephen.siddons@wyo.gov). In addition, the method for detecting mussels with PIT tags using a portable detector is described at https://www.biomark.com/custom-pit-tag-antenna-systems/. A link to the presentation by this group on transplanting mussels in Wyoming is at: https://www.youtube.com/watch?v=zosRA33cgy0

2. Method for estimating the long-term trend in abundance at each long-term monitoring site

In Attachment A and the Master Plan, proponents do not describe the method for estimating the trends in abundance or density at long-term monitoring sites. For example, if past estimates of CPUE at long-term monitoring sites are adequate, then regression or time-series analyses could be conducted to detect significant trends. In contrast, if future sampling of individually

marked mussels is repeated over seasons and years, then more sophisticated mark-recapture models (e.g., Cormack-Jolly-Seber; see Ohlman 2019) can be used to measure trends in abundance.

Proponents report in Table 5-1 and 5-2 that they will use Mark-and-Recapture of tagged mussels to estimate abundance during post-supplementation monitoring but not whether this will be used at long-term monitoring sites. Without addressing detection probability, visual surveys of mussels at long-term monitoring sites are estimates of CPUE, which have unknown bias and are not useful as indicators of true abundance.

C. For all methods used to measure distribution and abundance

1. Relationships between results of former sampling methods versus revised methods

After the proponents develop standardized methods for measuring distribution (presence/absence, or occupancy) and abundance/density, it will be necessary to calibrate across methods so that past data can be compared with new measurements. For example, eDNA might reveal that past methods used to determine mussel distribution at sites were capable of detecting them only 50% of the time when they are actually present (i.e., a site-scale detection probability of 0.5). However, no specific information was presented about a plan to collect data to determine these calibrations. This work is important because the early monitoring surveys appear to be essential for assembling the habitat suitability model, so seamless continuity in the monitoring program is required as new methods are implemented.

2. Document the sampling methods in the Master Plan and in MonitoringMethods.org

In Tables 5-1 and 5-2 the proponents report five sampling methods to be used for four objectives (e.g., Status and Distribution, Long-term Monitoring). One of these, eDNA, is a pilot effort to develop improved estimates of presence/absence. Another, Mark-and-Recapture, could provide quantitative estimates of abundance/density, and also survival and immigration/emigration if carried out over multiple years with sufficient numbers of mussels (see above). However, the other three (CPUE, Line transect, Random quadrat) yield estimates of relative abundance with unknown bias that is different among age/size classes and so are not useful for estimating true density or the analysis of its trends.

In addition, no specific information is presented on exactly how these methods are employed, such as the how sampling sites are delineated, the number of transects snorkeled, or their orientation with the channel. The proponents documented their current protocol used for collecting data to date but did not provide specifics.

3. Update the maps for each subbasin (Figures 4.2-4.6) to show all sites sampled

The proponents updated their maps (Figs. 4.2-4.7) to show sites sampled where mussels were apparently absent, and they are now much more informative. For example, it is now clear that in the Umatilla and Walla Walla rivers many sites were sampled, but mussels were not detected at most of them. Whereas in the John Day tributaries, mussels were detected at almost all sites sampled. In contrast, it is unclear to the ISRP why only a few sites have been sampled in the Tucannon and Touchet river basins, and none in the Powder or parts of the Malheur river basins that occur within the ceded territory.

4. Consultation or collaboration with experts in these fields

The response indicates that the proponents are collaborating with Dr. Jim Peterson at Oregon State University and Dr. Jeanette Howard at The Nature Conservancy (previous project lead for CTUIR FWMRRP) to develop subbasin-specific habitat suitability models using long-term and other monitoring data from CTUIR research. However, it does not provide details on the specific collaborative activities, anticipated products, and timelines for meeting objectives. Moreover, the proponents do not indicate that this collaboration, or collaboration with another statistician, includes help developing a probabilistic sampling plan or robust methods for estimating occupancy and true density/abundance, which are also critical uncertainties for this program.

See Condition 10 above for our suggestion for the proponents to develop an advisory group to augment the proponents' existing expertise.

II. Salvage and translocation of mussels

The ISRP continues to consider salvage of mussels to be an exceptional opportunity to estimate detection probability and provide mussels for translocation or augmentation. The proponents report (p. 21) that salvage of mussels and translocation to other sites is a low priority, owing to 30-70% mortality. Carey et al. (2015) reported about 40% annual survival for translocated adult mussels in a Virginia river, versus about 60% for releasing laboratory propagated sub-adult mussels. Therefore, if survival of salvaged mussels is similar to that study, the opportunity to translocate hundreds to thousands of salvaged mussels seems an excellent opportunity, assuming proper precautions to prevent disease and maintain genetic integrity are taken. Salvaging mussels is much less labor and time intensive than the propagation of mussels described in the Master Plan, where years will be spent in attempts to produce 500 mussels. We note that these will also have less than 100% survival when transplanted, and perhaps similar to the 60% reported by Carey et al. (2015).

Salvage sites also provide the opportunity to measure detection probability of individual mussels by excavating quadrats after counting mussels. These efforts would provide data to fit models of detection probability given habitat variables (e.g., depth, substrate, embeddedness, temperature), and allow expansion of counts from other sites to estimate true density.

The ISRP presumes that salvage operations likely occur during 1) planned work in channels to repair roads, bridges, culverts and conduct fish habitat restoration, and 2) emergency repairs to infrastructure after storms. Gathering information about the first type would allow the proponents to plan well in advance for salvaging mussels, including disease and genetic testing. In the second type of operation, mussels could be gathered and transported to the laboratory for holding, followed by disease and genetic testing, assuming these mussels survive transportation well.

The ISRP is uncertain how many mussels are available to salvage in an average year but urges the proponents to make advanced preparations for salvage from planned sites of the first type above, and also plan holding space for mussels that can be salvaged during emergency repairs of the second type. If mussels are commonly available for salvage, then even modest survival rates after translocation offer a valuable opportunity given appropriate planning.

Use of salvaged mussels for translocations or augmentation should be explicitly linked to the genetics management plan.

III. Artificial propagation and augmentation/reintroduction of mussels

The ISRP is concerned that the laboratory space for propagating mussels, currently a single 5 X 5-foot space, will be insufficient for the project when it moves beyond the pilot phase. For example, a single event (e.g., virus outbreak) could destroy years of work and a large portion of the program's efforts if there is only one facility. The ISRP urges the proponents to begin planning now for one or two more separate propagation facilities, to justify the investments and prevent loss. In addition, the proponents are asked to describe a broad, general plan for expanding facilities in 5-10 years, if mussel propagation is successful.

A. Basis for the quantitative objectives (e.g., 500 propagated adult mussels)

The response indicates that the numbers identified in the objectives are based on discussions with experts in mussel propagation and restoration (R. Hoch, North Carolina Wildlife Resources, Marion, NC; J. Kunz, USGS-CERC, Columbia, MO). The ISRP commends the project for consulting with national experts. Nonetheless, the response does not explain the biological basis for determining the number of organisms to be produced for reintroduction. For example, have data on survival through various life stages (such as in Table 3-2) been used to calculate how

many mussels are needed per site to produce juveniles and future adults that meet any criterion for a viable population? Have the implications of these numbers on the genetic integrity of the translocated populations been addressed? The ISRP urges the proponents to work with regional experts to develop a simple viability model for this purpose that considers both demographic and genetic risks.

The ISRP is concerned that the goal of 500 mussels may be simply based on the available laboratory space to propagate them. Although the proponents intend to use Adaptive Management to make program adjustments, the ISRP is concerned that since the process of artificially rearing adult mussels is long, any adjustments needed to produce more adults will take years. Considering the current status of some species and populations, an analysis of population viability could reveal that the current objective for propagation is inadequate. A more rigorous biological basis for the propagation component of the project is needed.

B. Measures to ensure an adequate population of fish hosts

The proponents indicate that potential restoration sites will be surveyed visually for host fish by snorkeling. They indicate additional data may be available from ongoing habitat restoration projects. These are both useful approaches but have yet to be developed. As described above, the ISRP suggests considering use of eDNA to map the presence of suitable host fishes.

Understanding the distribution and minimum abundances of host fishes required to develop viable mussel populations is critical to planning mussel restoration. The ISRP urges the proponents to consider a landscape-level analysis of the known distribution and abundance (if possible) of potential host species, to provide the critical information needed for their adaptive management of mussel restoration.

C. Methods of analysis to detect trends that indicate success or failure

In the 2021 review, the ISRP recommended that the methods involve:

a. Marking mussels with external tags or PIT tags to allow identifying individuals
b. Repeated surveys each year at each site to estimate detection probability
c. Analysis of the set of data over 5 years of sampling
d. Consider the entire set of sites simultaneously

In Table 5-13, the proponents report that they will measure survival but provide no details about how mussels will be sampled to estimate this, given imperfect detection. Evidence for success, qualified success, or minimal survival depends on these data and the analysis of them. Without suitable methods, the huge investment of time and funds on mussel propagation could lead to no useful conclusion.

The proponents' collaboration with Dr. Peterson of OSU could lead to a comprehensive design involving PIT-tagging mussels that are translocated at the planned treatment and reference sites, "recapturing" these on a regular basis using PIT-tag detectors, and analyzing these data to derive robust estimates of survival. In addition, analyzing the entire set of information collected across sites in a single comprehensive analysis reduces uncertainty in detection probability, thereby improving the precision of survival estimates.

D. and E. Risk assessment of genetic consequences and effects on fitness of artificial propagation, and a Hatchery Genetic Management Plan (HGMP)

The ISRP commends the proponents for preparing a draft freshwater mussel Hatchery Genetic Management Plan, presented in their Appendix A, and describing their genetic management plan in Section 5.7.2. We urge the proponents to include in their advisory committee a scientist qualified to help further develop this plan as the project moves forward. The ISRP expects that we will receive additional detail and will review the Hatchery Genetic Management Plan in the future if the project's propagation efforts are successful and continue.

F. Vision for the future - anticipated expansion or additions

The ISRP commends the proponents on developing a Master Plan that represents a more thorough and potentially effective framework than the previous project structure and operations. The proponents provide a workable vision for the future to be guided by adaptive management, with the assistance of their partners and advisory committee. This is an evolving program and, as such, needs to be nimble in the face of uncertainties, the results from ongoing syntheses of their data sets, and the emergence of new knowledge. This is an important project and one of the few mussel restoration efforts in the western U.S. The ISRP looks forward to learning about the continued progress as the proponents pursue their conservation and restoration program for mussels in the CTUIR ceded lands.

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