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Dear Diane:

Thank you for offering me the opportunity to review your report entitled "**River Herring Climate Change Workshop Report.**" The report compiles a large volume of useful information for which you and your team of workshop participants should be congratulated. To assist you in your efforts, I have tried to summarize below some of the areas in which information, especially synthesis, may be missing. I realize that your task is a monumental one and future activities cannot address all relevant concerns. I trust you will view my comments in the spirit that I offer them, i.e., suggestions that may improve future research and management efforts and help conserve these valued species.

Below, I start by making overall comments that identify information gaps (Peer review letter). Then I refer to relevant sections of the peer-review letter to respond to your specific queries A-C.

PEER REVIEW LETTER - GAPS IN THE REPORT

1. LITERATURE REVIEW IS VERY INCOMPLETE

Probably all alosine researchers and managers are saddened by the small volume of peer-reviewed literature on river herring. So, I was especially disappointed to see that even the small amount of existing literature on river herring distribution/ecology/behavior (relevant to global climate change) was not comprehensively reviewed here. The majority of the references appear to be written by the workshop participants. Perhaps a more thorough literature review is in the petition that addressed the five factors identified in Section 4(a)(1) of the ESA. I assume that the literature was not reviewed because no one was charged with this task, but it is a major oversight. Many of these basic river herring ecology issues are directly related to possible impacts of climate change on these fish.

One example of a literature gap is predation. Unquestionably, ecotothermic predator-prey interactions will be affected by changes in water temperature, discharge, salinity, productivity, and other components of the food web. The interactions proposed for striped bass and river herring (and other relevant components of the food web) need to be addressed in any comprehensive review of river herring and climate change.

In addition, a few of the many published papers that could help put together the complex puzzle of how climate change might affect river herring are: Yako et al. 2000; Yako et al. 2002; Iafrate and Oliveira 2008; Frank et al. 2011; Mather et al. 2012; other research by J. Hightower, A. Overton, D. Post's lab (with A. Walters), K. Limburg, the 2012 Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science Volume on Shad and Herring (4:1), and Franklin et al. 2012.

2. A CRITICAL AND INTEGRATIVE SYNTHESIS OF THE LITERATURE ON RIVER HERRING IS NEEDED

Even when the relevant, existing literature is reviewed and compiled, a critical synthesis is needed that evaluates not just what we know but also what we do not know (but need to know). A concise and critical summary of what is known about drivers at each life stage could be useful. Also useful would be a thoughtful discussion of the types of data related to temperature, discharge, food, predators, and salinity that are needed to understand coast-wide trends (as they could be affected by climate change). Wilson's review of temperature is extensive (and she has done a good job of compiling what is available). However, when we think about all of the information that is needed to understand how climate change might affect river herring, the available temperature data are woefully inadequate. For example, there is no information on temperatures for outmigration (not Wilson's fault - I don't think these are available in the literature). Collette and Klein-MacPhee (the bible that we all love and use) is the source for many of these temperature data, but is, in fact, a compilation of very old sources. On the other hand, your report contains many pieces of temperature data that are listed as separate topics, but could be synthesized and integrated into the existing temperature table.

Although freshwater and marine expertise is represented, the links between these perspectives could be strengthened. For example, is salinity important or not? Sections of the report discuss potential changes in salinity and existing research on salinity but many statements in the report suggest this variable is not important. Perhaps, the authors of the report could integrate this information to provide a more consistent perspective.

A university researcher could provide this synthetic review of river herring life history, behavioral, and ecological literature and data needs.

3. COMPLEXITY OF THE PROBLEM IS NOT DEVELOPED

The report understates the complexity of the problem, especially interactions among abiotic and biotic drivers at each life stage, factors affecting transitions between freshwater-marine, and variation among rivers and years. Anadromous fish, including river herring, are very hard to conserve because their life history is composed of a series of life stages that are affected by different combinations of abiotic and biotic variables linked together by migrations/habitat shifts. To make a difficult conservation issue even more problematic, each run may have adapted to different gradients of temperature, habitat, predators, and timing patterns. As a researcher, I

believe the river herring puzzle is solvable but I do not think we do ourselves any favors by understating the complexity of the problem. I would have liked to see some of this complexity addressed in the background and included more explicitly in the hypotheses. One of the outputs of this workshop, and indeed the ESA petition, could be a thoughtful research program that would allow us to understand some of these issues within the next 10 years.

4. SYNTHESIS IS NEEDED THAT GOES BEYOND A LAUNDRY LIST OF ISSUES

The report reads like a laundry list of issues. To be of use for future research and decision making, the report and recommendations need to be integrated into fewer, more detailed, and more realistically-complex issues.

5. INADEQUATE ATTENTION IS PAID TO HUMAN IMPACTS

For anadromous fish, interactions among fish, climate change, and human impacts, (especially dams, fishways, water withdrawal, land use patterns that affect flow regimes and water quality) are important. Humans modify almost every part of the freshwater environment that river herring use so human impacts need to be discussed in a more comprehensive, synthetic way that includes fish life history, variation across systems, changes in water temperature, precipitation, discharge, salinity, and the food web. For example, [redacted] have shown in a modeling study of Atlantic salmon smolts that dams can kill fish at some distance from the dam by delaying egress from the river and forcing salmon to be in the river when spring water temperatures reach lethal levels. Thus, fish survival is an interaction among dams, discharge and temperature where discharge and temperature vary seasonally and annually (Marschall et al, 2011). An isolated approach using static values of individual variables, especially related to human modifications of the environment, is not going to save river herring populations along the coast.

Marschall, E. A., M. E. Mather, D. L. Parrish, G. W. Allison,. J. McMenemy. 2011. Migration delays caused by anthropogenic barriers: dams, temperature, and success of migrating salmon smolts. Ecological Applications, 21: 3014–3031

6. DATA NEEDS SHOULD BE MORE CLEARLY STATED

As many participants in the workshop state, relatively little , good data exists on most variables of importance (fish trends, temperature, discharge). A specific research plan with detailed data needs would be useful to strategize on future directions.

7. A BETTER LINK IS NEEDED AMONG CLIMATE CHANGE MODELS, LOCAL DATA, AND QUESTIONS RELEVANT TO RIVER HERRING

Climate change modeling, at present, predicts changes in air temperature and precipitation, usually on a relatively large spatial and temporal scale. Fish are affected by water temperature and discharge (e.g., precipitation combined with ground water and land use) at relatively small spatial and temporal scales. Any examination of river herring and climate change needs to link climate models with characteristics of specific systems and ask questions about how the absolute thresholds and rates of change in ecologically meaningful variables will affect river herring, This will be especially important as fish transit from one habitat/lifestage to another. I do need see a satisfactorily detailed conceptualization of the climate change problem in the current report.

BTW, I do not think precipitation can be equated with discharge without information on land use and ground water.

Also, climate modelers need to work with biologists familiar with river herring ecology to make sure the correct variables are modeled.

7. ADDRESS MULTIPLE CAUSATION

Many parts of the report review trends, then comment that the trend data are confounded by other variables (e.g., sampling, climate, harvest, or other variables, pages 21-23). Problems with and ways to deal with multiple causation need to be addressed if these descriptive data are to be useful.

RESPONSE TO SPECIFIC QUERIES (A-C)

A. In general, does the report include and cite the best scientific and commercial information available on the species and/or climate science to assess potential impacts?

Whereas the report contains useful information, as stated above, much needed scientific information is missing including a thorough literature review, syntheses, a conceptual framework for the interactions among components (life stages, habitats, and potential drivers), a detailed conceptualization of the climate change-temperature-discharge problem.

B. In general, are the hypotheses included in the report sound and derived logically from the information available?

The hypotheses are frequently interesting. However, multiple falsifiable options that can be tested are not identified. The brief and unconnected pros (supporting) and cons (information against) below each "hypothesis" were not useful to me. This section needs to be better justified and developed, then linked to testable outcomes.

C. Are there additional considerations on the topic that should be considered and/or reiterated from the workshop report to consider when assessing impacts of climate change on river herring?

In my peer review summary above, I have identified a number of gaps. Filling these would assist in the restoration and conservation of these valued species.

Please contact me if I can assist further. I wish you the best of luck.

[redacted]