Research recommendations for TEWG Climate Change Subgroup: Effects of climate change and variability on river herring"

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Climate change effects on river herring

March 16, 2016

A total of 25 research recommendations were identified based on our discussions during teleconferences over the last year. The group narrowed a larger list of research recommendations made at the NMFS 2012 workshop on the potential impacts of climate change on river herring to only those research projects that directly related to climate change. Some research recommendations were added to the list as we heard talks from various experts in the field over the course of our conference calls in 2014. Thus, we emphasize that all the research priorities were identified as warranting attention to understand the effects of climate change and variability on river herring. Many of this research would benefit from occurring simultaneously. For example, if physiology is to be effectively incorporated into population models that are driven by global climate models, scientists from these areas of expertise should work closely together.

Nine members of the 16 active TEWG Climate Change Subgroup submitted their individual rankings. Many recognized that their rankings after about the first 15-20 were somewhat arbitrary. To summarize the rankings we averaged the ranks and used the standard deviation as an indicator of "agreement" among the Subgroup as a whole. There was very good agreement on the three research recommendations ranked most highly as indicated by the low standard of deviation associated with their rankings. The top 3 research recommendations were:

1. Environmental tolerances and thresholds (e.g., temperature, salinity, water flow, pH, DO) for all life stages
2. Behavior and physiological studies related to climate sensitive environmental variables
3. Need continuous data on river flow and temperature in same systems where adults and juveniles are monitored

While the group as a whole ranked "River run and juvenile survival data measured with same methods along a latitudinal gradient" as the #4 research priority, the standard deviation was high because some individuals recognized this as a coordination issue rather than a research issue. Additionally if sampling protocols are changed there are calibration issues and potentially a loss of historical time series. There was a wide range of estimates for cost of this research item because the cost to monitor across the geographic range of river herring is high, but monitoring already exists so changing the way we monitor might be cost-effective. Other research priorities that ranked high were "A population model that would allow exploration of the relative influence of climate change vs. other factors such as habitat alteration, fishing, bycatch etc." and some members noted that there would have to be strong coordination between members of our subgroup and members of the Stock Status Subgroup.

The top 10 research priorities all related to better understanding the effect of climate-relevant variables, specifically temperature and flow, on river herring growth and survival. Without such basic understanding on the physiology of these species, it will be difficult to anticipate how climate change will impact these species. The group as a whole also ranked research on basic physiological and environmental endpoints as being able to be completed in the near term because some information exists for temperature tolerances (Greene et al. 2009) and analysis of historical data has been or is being conducted (Tommasi et al. in prep, Tommasi et al. in press)

While research priorities to project the effects of climate change using Global climate models ranked lower and may be more expensive than other research, it is still important to explore how climate change may impact fresh water, estuaries and marine ecosystems by linking habitat or population models of river herring with output from Global climate models. For example, research based on previous versions of climate models indicates that anthropogenic climate change could have a significant impact on river herring in the open ocean (Lynch et al. 2014). However, a similar exercise should be done in freshwater systems, as we do not know whether the environmental bottlenecks exist in the marine, freshwater or estuarine phase of river herring's complex life history. In addition, climate models and dynamical and statistical downscaled output from these models indicate that the atmosphere will warm significantly over the entire geographic range of river herring, and that much of the northeast US will be wetter during the cold season in the future (http://www.greateratlantic.fisheries.noaa.gov/protected/riverherring/tewg/climate/alexander.river.herring.tewg.8-14.pdf). These changes could have significant impacts on river herring, when they are in fresh water or estuaries. We anticipate learning a great deal from analysis of future climate change, even if more definitive and higher resolution results become available in the future. Of the research related to making climate projections for river herring the top three were:

1. Continuous climatologies for marine estuarine and freshwater habitat
2. Development of models and methods to project effects of climate change into the future
3. Downscaled temperature, snow pack, and stream flow climate projections in both marine and freshwater systems at a high spatial resolution

There was also very good agreement on the lowest ranked research recommendations, the lowest ranked research priority being "how climate change and environmental factors influence hybridization rates." High resolution models and projections for flood timing and sea level rise were also ranked at the bottom because little is known about how these factors affect river herring. The effects of ocean acidification on river herring are completely unknown. While the general research recommendation "Ocean acidification impacts" ranked near the bottom, determining the physiological thresholds to pH was the highest ranked research priority. Fish are also most sensitive to low pH/high CO_2 in the early life stages when river herring are in fresh water, likely before the acid-base system is developed. Freshwater systems vary widely in their buffering capacity and acidification of freshwater systems from other anthropogenic stressors could be an important source of acidification in addition to atmospheric CO_2 and impact the early life stages of river herring. A review of coastal ponds in New England in the 1970s and 1980s might give insight on how changes in pH affected ecosystem productivity and river herring recruitment. Also, because diadromous fishes like river herring have a relatively flexible osmoregulatory

system to be able to travel between fresh and marine systems, they may have physiological mechanisms to cope with ocean acidification. As noted in our August 14, 2014 meeting, low dissolved oxygen and acidification, which co-occur in many estuarine systems (e.g. Chesapeake Bay), should be added to this subgroup's list of climate stressors. This is related to climate if precipitation increases and nutrient runoff increases as a result of climate change and exacerbates these two stressors. Nutrient runoff also increases from population growth and land use change so climate and land use change are two drivers that must be examined simultaneously rather than as isolated factors.

Consideration of cost

Many people who ranked the research priorities did not provide estimates of costs or listed relative costs only for the types of research with which they were most familiar. The most cost effective research recommendations were to use historical information on water temperature and flow in rivers, baseline habitat data and link it with data that has already been collected from historical river runs. Many recognized this as cost effective because the data already exist and much of it has been analyzed (Tommasi et al. in press).

The most expensive options were in some cases those research recommendations that were also recognized to be long-term programs that encompassed many of the more specific research priorities listed. For example, many recognized that "Development of models and methods to project effects of climate change into the future" and "Quantify optimal habitat for all life stages historically and in the future" were "catch-all" research priorities and would be expensive because of the length of time to complete all the steps necessary to meet the overall goal of these research priorities. Many of the lowest research priorities were also what the group perceived to be the most expensive or had the greatest cost uncertainty (indicated by high standard deviation). As noted above, many recognized that their rankings after about the first 15-20 were somewhat arbitrary.

Table 1: Summary of individual rankings (with standard deviation) of research needs from the TEWG Climate Change Subgroup, including average cost, time frame and comments. Cost is reflected as: $ =1-9K; $$ =10-99K; $$$ =100-199K, and $$$$ =>200K. Time frame is reflected as: "E" =Exists already, "S" =Short-term(1-3 yrs); and "L"=Long-term (3+yrs).

	Rank	Standard Deviation of rank	Average cost	Time frame	Comments
Environmental tolerances and thresholds (e.g., temperature, salinity, water flow, pH, DO) for all life stages	1	3.09	$$$	E-S	Some information exists, but critical thresholds are not available for most life stages
Behavior and physiological studies related to climate sensitive environmental variables	2	3.20	$$$	S-L	
Need continuous data on river flow and temperature in same systems where adults and juveniles are monitored	3	3.26	$$	S-L	This means adding river flow and temp measurements to rivers that are monitored for river herring; coupling USGS with state monitoring efforts
Need river run and juvenile survival data measured with same methods along a latitudinal gradient	4	8.15	$$$	S	
Historical relationships between river herring abundance and distribution with environmental variables	5	4.29	$$$	E-S	Some studies exist, but need comparison and wide geographic range
A population model that would allow exploration of the relative influence of climate change vs. other factors such as habitat alteration, fishing, bycatch etc.	6	6.36	$$$	S-L	Build upon MARSS model by K. Curti
Link historical river runs to water temperatures and flow	7	5.04	$$	E-S	

Environmental cues that lead to spawning migration and juvenile egress	8	4.39	$$	S	
Impacts of stream flow on passage and interaction with barriers	9	6.54	$$$	E-L	Need this before we can apply climate scenarios
Quantify optimal habitat for all life stages historically and in the future	10	7.18	$$$	S-L	
Continuous climatologies for marine estuarine and freshwater habitat	11	6.90	$$$	S-L	Challenging because of different data types
Development of models and methods to project effects of climate change into the future	12	6.78	$$$	E-L	
More information on river herring at the extremes of the range to see the most acute climate change effect (e.g., on blueback herring in the St. Johns River, Florida; alewife in North Carolina)	13	4.92	$$$	S-L	Time series analysis will be long term because it will take time to collect enough annual data
Baseline habitat information to provide foundation for temporal and spatial comparisons	14	6.42	$$	S-L	Need to know more about tidal freshwater and estuarine habitat use especially for blueback herring Should be done by habitat group
Downscaled temperature, snow pack, and stream flow climate projections seasonal in both marine and freshwater systems at a high spatial resolution	15	7.71	$$$	S-L	Exists for land variables by NARCCAP, IS NARCCAP being updated with AR5 models?
Linking river herring to dynamical and statistical downscaling products	16	8.07	$	E-L	
Homing rates to determine how quickly fish may be able to adapt to change	17	7.53	$$$	E-L	

How flood types and timing affect recruitment, migration timing (of adults and juveniles), juvenile growth and juvenile survival	18	6.22	$$$	S-L	
Statistical downscaling of temperature and river flow	19	6.62	$$	E-L	
How flood magnitudes and frequencies in watersheds changes in systems impacted by human development and those that are not	20	6.04	$$$	E-L	Not useful until we know more about fish passage under different flow regimes
Dynamical downscaling of the nearshore environment to assess prey field for juveniles entering the marine habitat	21	4.70	$$$	S-L	
Ocean acidification impacts	22	8.33	$$$	S-L	
High resolution elevation models to project inundation due to sea level rise to project river herring inshore habitat	23	6.41	$$$	S-L	Not useful until we know more about inshore habitat use
Historical change or future projections in flood timing for the Northeast	24	6.08	$$-$$$	S-L	USGS model applied nationwide
How climate change and environmental factors influences hybridization rates	25	3.62	$$$	S-L	Need to know success of hybrids first Seems premature until we know more about hybrids in general

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