Climate Change and the Future of Freshwater Fisheries

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Key Points

- Climate change will cause profound environmental and biological changes during the course of your career.
- Prioritize and be efficient with your time and allocation of limited conservation resources to have the biggest long-term effect on fisheries resources.
- Strive to collect long-term monitoring data and archive it in digital databases so that trend assessments for freshwater ecosystems are improved.
- Realize that the decisions you make in the next few decades may have important consequences for fisheries resources a century from now.

My first awareness of the importance that climate has for fish came during my summer field seasons as a Ph.D. student at the University of Wyoming. While conducting electrofishing surveys in the climatically diverse Salt River basin along the mountainous border between Wyoming and Idaho, I observed spatial patterns in species distributions and abundance that strongly paralleled gradients in stream temperature. At the same time, through the research that Dr. Frank Rahel and his students were conducting at the same university, I became aware that climate could change in ways that might have significant repercussions for fish distributions. A few years later, climate change moved into the American consciousness with the sensation around Al Gore's movie *An Inconvenient Truth*, and peer-reviewed papers began appearing in the literature that documented environmental trends consistent with global warming. My interest was piqued, and I began seriously digging into the topic of climate change to better understand how freshwater ecosystems could be affected. What I found transformed me and, because of the profound implications that climate change has for everything aquatic, caused me to transform my research career.

As background for this vignette, it is worth noting that air temperatures measured at weather stations across the contiguous United States were warmer in 2012 than any year since direct measurements began 117 years ago (Figure 1). Rather than being a random event, those record temperatures are symptomatic of the long-term warming trend in the Earth's climate during the past century. The majority of warming is caused by human economies and population growth, which have altered the chemical composition of the atmosphere through the release of carbon dioxide and other heat-trapping greenhouse gases. The Earth's temperature is now warmer than any time in the previous 10,000 years, which

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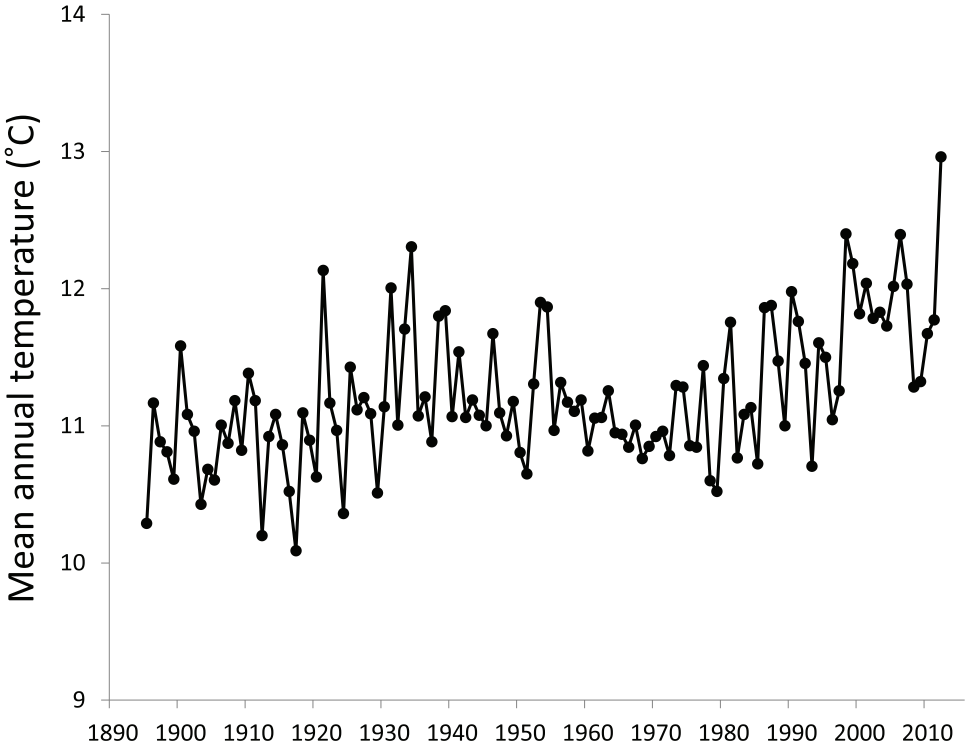

FIGURE 1. Mean annual air temperatures from 1895 to 2012 for the contiguous United States. Data are from the National Oceanic and Atmospheric Administration's National Climatic Data Center.

roughly coincides with the development of human civilization. Barring a series of major volcanic eruptions in future decades, or unforeseen breakthroughs in clean energy technology, it is highly likely that temperatures, and record warm temperatures, will continue to increase through at least the middle of the 21st century. Global warming, and the series of environmental, habitat, and fish population trends that accompany it, will be a defining theme in your career and the careers of fisheries professions that follow you.

Considerable evidence already exists for changes in freshwater environments that are associated with the historical increases in Earth's temperatures (see Recommended Readings). Lake and stream temperatures have been increasing while precipitation patterns and stream hydrologies show a variety of climate-related trends. Because fish and other aquatic organisms are ectothermic and confined to well-defined water bodies, their population dynamics and distributions must adjust to those changes. Adjustments consist of shifts in the timing of migrations, spawning, and other life history events, as well as poleward and upstream distribution shifts to cooler habitats. During those shifts, some species and populations are encountering barriers to migration, running out of room in ephemeral headwater streams, or being overtaken by shifting thermal conditions that cause local extirpations. Within the core areas of species' distributions, many populations are at no immediate risk, but even there, changes are occurring slowly that will cause habitat suitability to drift relative to the tolerances of individual species and communities.

Trends associated with climate change run somewhat counter to the "balance of nature" and "dynamic equilibrium" concepts that were central to natural resource education and stewardship in the 20th century. A dynamic disequilibrium is a better conceptual model for the way the world works now. The new model holds that aquatic environments are becoming more variable and gradually shifting through time as the Earth warms. Those trends are exacerbating the desire of growing human populations to have reliable water supplies. That means additional water development projects to store or divert water, and greater alteration of its movement across landscapes, which will have repercussions for freshwater organisms. Into this shifting milieu, nonnative species are being more frequently introduced or spreading from areas where they had previously been confined. A disequilibrial world is one that will systematically create winners and losers because species are predisposed either favorably or unfavorably toward the changes that occur. We have entered uncharted waters in many regards, and your generation is confronted with rapid changes at massive scales. You will have to learn, adapt, and evolve more rapidly to a greater set of challenges than your predecessors to be an effective resource steward in today's world. It will be important to seek out mentors and learn from those with experience in your new career field, but also realize that their experiences may be less of a guide than was previously the case.

More than ever, success will require clear goal setting, frequent reassessments as novel situations are presented, and communicating with diverse publics. In addition to traditional concerns about maintaining, improving, or understanding fisheries, you may find yourself confronted with questions about whether some long-term fisheries can continue to support harvest in the future. In other cases, broad geographical declines (or increases) in species that might once have been short-term phenomena may instead become the new normal as environmental trends related to climate lead to dissolution of contemporary biological communities and development of new ones. There will be questions and significant concerns from a public that is sometimes poorly informed and antagonistic regarding the issue of climate change. Some may question your credibility for even mentioning climate change and its effects on fish populations. Yet others will clamor for preserving biodiversity and native species within historical ranges that are no longer suitable for the species in question. Goals and management programs that were logical to your predecessors and seemingly achievable at the beginning of your career may become unrealistic in future years. At the same time, currently unforeseen challenges and opportunities will present themselves.

Navigating the complex environmental and social dynamics triggered by climate change requires broad understanding of many issues and superb communication and people skills. Push yourself to read and think broadly while continuing to hone your communication skills. Take extra writing and speaking classes while in school and look for opportunities to apply those skills after graduation. I was a terribly shy and nervous public speaker well into my 30s, but I took extra speaking classes during college and have always forced myself to prepare and give talks during my professional career. Though by no means a brilliant orator, I now give passable talks and am invited to do so frequently. One mentor early in my professional career, Bruce Rieman, was well known for his dynamic and engaging speaking style. Nearing retirement, he confided in me that he thought giving good talks was the most useful thing he ever did in terms of influencing other people. And how you influence and work with other people will be critical to building collaborative relationships and your effectiveness over time. No one person or organization can do it all. Teams of professionals with complementary skills are required to address climate change, so developing partnerships within your organization, between your organization and others, and across disciplinary boundaries will be key to leveraging resources and team building. Learn what your biggest strengths are as a researcher, manager, database designer, geospatial analyst, or team leader, and contribute your skills accordingly. People want to be engaged in meaningful work, and issues surrounding climate change and fisheries present young professionals a wealth of such opportunities.

Developing better information, and systems for creating information, is a powerful teambuilding endeavor that may also reduce many of the uncertainties about how climate change affects fisheries. Information ultimately flows from data and models that allow us to accurately describe the status and trends of aquatic resources. At this point, however, most of what we know is based on studies and monitoring efforts that are of short duration and small spatial extents, which limits our ability to think and manage at the broader spatial and temporal scales that are required by climate change. In some instances, developing the necessary information for key parameters like species distributions and abundance, stream and lake temperatures, or stream discharge may be accomplished simply through better coordination of sampling efforts among organizations or by aggregating existing data. One project I participated in, for example, developed an interagency stream temperature database for dozens of agencies in the northwest United States. The project was prompted by the fact that there were literally millions of temperature measurements in existence but the data were not usable because they were scattered among hundreds of biologists. Once a centralized database was created and made broadly available through a Web site, it provided the regional aquatics community with a resource worth millions of dollars. Far more valuable, however, is the information that the database continues to yield for better decision making and improving the efficiency of new temperature monitoring efforts among multiple agencies.

Because climate change is ultimately about gradual trends in the environment, long-term monitoring programs are especially important for describing the dynamics of freshwater systems. I can still hear Dr. David Willis in my undergraduate fisheries management class at South Dakota State University intoning, "Collect the same data, in the same way, at the same time and place each year" with regards to developing monitoring records. It is not rocket science but it gets the job done and, over time (e.g. several decades), may provide direct evidence regarding how climate is affecting species composition or habitat quality at specific sites. The longer any trend monitoring program can be maintained, the more valuable it becomes, so early in your career, seek out opportunities to establish, or participate in, monitoring programs. Modern temperature and flow sensors are relatively inexpensive and can record continuous measurements for many years, so in some instances, monitoring networks can be established even with tight budgets.

Better data and information will provide an important foundation for decision making during your career, but are not panaceas. There will be difficult decisions ahead, sometimes with only unappealing options from which to choose. Being effective may mean picking the least bad option and prioritizing resources where they serve important needs in the short term while also accomplishing the most good over the long term (decades [and maybe centuries?] rather than years). You may not see, or be credited with, the ultimate benefits and consequences of some of these decisions, but they will be important determinants of fisheries resources available to future generations. As a simple guide to effective action, ask yourself where desired resources, values, and fisheries may be most resilient to future climate trends, where they are at risk of disappearing, and whether there are intermediate areas where intelligent and proactive interventions could figure decisively in the outcomes? That final case is where resources will be most profitably spent, and in some cases, the threat posed by climate change could be used to marshal resources for long-needed habitat improvements and restoration activities. Effective restoration in some instances could offset some of the detrimental effects of climate change because many aquatic environments are already significantly degraded. In cases where desired conditions are impossible to maintain, keep an open mind because doors to new possibilities will be opening. For example, it might be possible to facilitate the establishment of important new fisheries or biodiversity reserves for more southerly species that were previously limited by cold temperatures. In many rivers across the western United States, Brown Trout *Salmo trutta* and Smallmouth Bass *Micropterus dolomieu* appear to be rapidly expanding upstream and could provide significant angling opportunities if properly managed. In all cases, think about designing and implementing systems and management strategies that are resilient, are flexible, and have the capacity for adaptation and evolution in the future.

Conclusion

It has been said that it is impossible to ever step in the same river twice. That statement remains true, but now the river is flowing ever faster. Your generation of fisheries professionals faces challenges unlike any preceding generation. Climate model projections suggest that air temperatures will warm another 1–3°C by mid-century. Even at the low end of that range, more warming would occur in the first half of the 21st century than occurred during all of the 20th century. Human populations will also continue to grow, and their per capita consumption rates will be higher than today as living standards continue to rise. Given those changes, this century will be a monumental and transitional one for the Earth, aquatic resources, and the fisheries profession. The stresses placed on the natural world will be unprecedented, and significant changes are inevitable. The choices that human society makes, and that you make as a fisheries professional during your career, will play a large role in shaping the world a century from now. I do not envy you for the challenges that lay ahead, but exceptional times create exceptional opportunities and people. Many among you will rise to the occasion and do great things that ensure important fisheries legacies for future generations. I wish you the best in those endeavors.

Biography

Dan Isaak is a research fisheries scientist with the U.S. Forest Service Rocky Mountain Research Station Aquatic Sciences Laboratory in Boise, Idaho. He holds a B.S. degree from South Dakota State University, an M.S. degree from the University of Idaho, and a Ph.D. from the University of Wyoming. His research focuses on understanding the effects of climate change and natural disturbance on stream habitats and fish populations, stream temperature monitoring and modeling, development and application of spatial statistical models for stream networks, and use of digital and social media to connect people, information, and landscapes. He also writes the Climate-Aquatics Blog (www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/stream_temperature_climate_aquatics_blog.html).

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