

## Climate-Aquatics Blog #34: Part 2, Fish distribution shifts from climate change: Empirical evidence for range contractions

**Biological evidence of fish skies falling is almost nonexistent...**



Hi Everyone,

So as we saw last time, the fisheries community has definitely recognized the threat posed by climate change to aquatic critters this century. More than 20 bioclimatic models have been developed and published in the last two decades (graphic 1; [Blog #33](#)). Most of these predict large distributional shifts and range contractions in high profile species, so there's much on the line in terms of conserving biodiversity, maintaining important fisheries, and spending limited resources wisely (graphic 2). In contrast to the extensive empirical evidence available to confirm distribution shifts in many terrestrial plant and animal taxa ([Blog #31](#)), the evidence for aquatic biotas is very limited. This hurts us in two ways—by contributing to an “inertia of inaction” regarding tough choices that are better made sooner rather than later, and by running the risk of making poor decisions when we do act if the model predictions turn out to be wrong.

With this in mind, I'm always keeping an eye out for studies that provide good evidence of range contractions in fish populations related to recent climate trends, but as far as I can tell, so far there are only 2 (if I'm missing some, I'd love to have them brought to my attention). The first study is by Hari and colleagues on brown trout in Switzerland, and so far, represents the seminal piece of work on the topic. This study is so comprehensive, in fact, that it was highlighted in an earlier blog ([#10](#)) on stream temperatures for the insights it provided about regionally consistent stream warming trends related to climate change, climate cycles, and glaciers in Swiss streams.

Today, to quote Paul Harvey, we'll tell “the rest of the story” from Hari et al. and what was done with the 24 years of consistent stream temperature monitoring data at their disposal. In the second phase of the study, thermal bioenergetic criteria for growth and survival of brown trout were compared to thermal conditions in 87 river sections across the country for which temperature data were available. This allowed the authors to make much more precise local predictions of potential effects on brown trout during a warming period from 1978-2001 than would have been the case from broad-scale bioclimatic models (& as we'll see in future blogs, this precision is often needed to tease out the gradual changes caused by climate change). In the

third phase of the study, these predictions were compared to trends in population abundance over the same period.

Many useful details are in Hari et al, but the take home is that over the 24 year period encompassed by the study, catch rates and trout densities declined dramatically in the warmest, lowest elevation river sections that were close to being too warm for the species at the outset (graphic 3). Populations declined less rapidly in sections with intermediate thermal conditions, and showed no trends in the coldest river sections. That pretty well matches what the most basic predictions of climate change and warming effects should be for an ectothermic species at thermally mediated boundaries during periods of warming. However, it was also never the case that dead fish just floated up everywhere one day when a critical temperature was exceeded to make the temperature linkage obvious. Instead, the pattern was subtle and protracted, exacerbated by increased incidence of disease, slower growth and survival, etc., etc. And that's often going to be typical of how climate effects manifest in many populations, it'll be a very slow process that interacts with other stressors to chip away at populations (although these gradual trends may also help set up populations for catastrophic events in certain contexts as we'll see in a future blog), which means long-term monitoring datasets are often going to be mandatory for discerning the climate signal from the noise.

OK, so the second study is by Winfield & colleagues and looks at long-term population trends in lake populations of Arctic char across the United Kingdom. And that right there should tell you we've got to be at the southern extent of the species' range (& thermal tolerances) because "Arctic" generally isn't the first thing that pops to mind when thinking about the landmass inhabited by our trans-Atlantic friends. Regardless, the premise of the study is much the same as Hari's—look at many populations over a long period of time spread across a range of thermal conditions (graphic 4). What Winfield finds is that the southern-most populations, located several hundred kilometers away from the northern population, have all undergone significant population declines over the recent 20 – 40 year period. The northern population, in contrast, appeared to also decline, but by nowhere near as much as those to the south. A variety of factors could play roles in these declines, but the authors do a good job of addressing them, so here again, we see a pattern that matches the basic predictions derived from the bioclimatic models & that other investigators have observed for other taxa ([Blog #31](#)).

And for fish, that's it. Those are the 2 best studies I've seen documenting the process of range contraction related to climate change in previous decades. Now we just need a few dozen additional studies from other continents to get a better sense of how widespread this phenomenon may ultimately be for aquatic biotas & how the biological rates of change relate to environmental rates ([Blogs 10, 11, 13, 16, 17, 18, and 23](#)). Ideally, some of those studies would be done within the same areas, & for the same species, that bioclimatic models have been previously developed so that we can test, refine, and improve the models to the point that they begin to provide sound scientific information at resolutions useful for prioritizing local conservation efforts. We're not there yet, but I suspect we'll be surprised at how much farther down this path we are in the next 5 years. The current state of knowledge within the fisheries community has strong parallels to where things were within the climate science community 30 – 40 years ago when lots of models were being developed and a consensus of predictions emerged that global warming was likely (graphic 5). Subsequent to those model predictions, we've accumulated decades of empirical

evidence from global temperature monitoring networks indicating that the Earth has indeed become warmer and that the climate models were more or less right (graphic 6). I suspect a similar dynamic will play out for fish in future years as we start to look more closely in more places for the biological fingerprint of climate change.

Next time out, we'll take a quick look at the evidence for range expansions in fish populations where temperatures have previously been too cold to support certain species, & thereafter, we'll spend some blog time thinking in detail about how to accurately discern whether the fish skies are falling in your local streams and the rates at which they may be doing so.

Until next time, best regards,

Dan

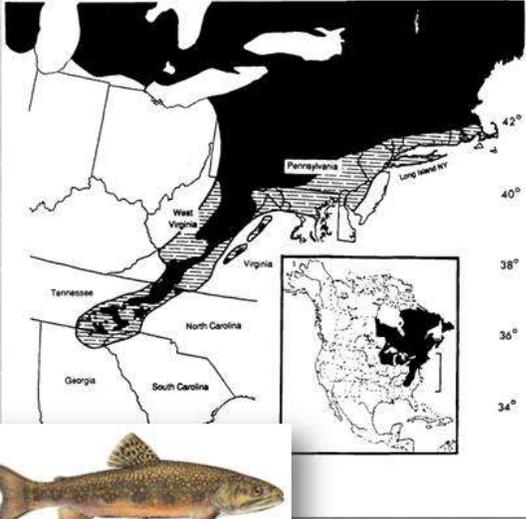


## Model Predictions of Fish Distribution Shifts for 20+ Years Now...

**Effect of Climatic Warming on the Southern Margins of the Native Range of Brook Trout, *Salvelinus fontinalis***

J. Donald Meisner<sup>1</sup>

Meisner. 1990. *CJFAS* 47:1065-1070.

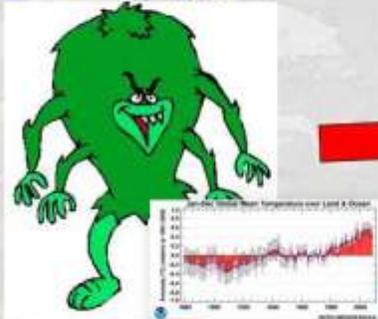


**Also...**

- Eaton & Schaller 1996
- Keleher & Rahel 1996
- Rahel et al. 1996
- Mohseni et al. 2003
- Chu et al. 2005
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Almodovar et al. 2011
- Wenger et al. 2011
- Etc.

# There's A Lot on the Line...

## Climate Boogeyman



## Recreational Fisheries

Low Flows Prompt Fishing Closure On Upper Beaverhead River And Reduced Limits On Clark Canyon Reservoir

Wednesday, September 29, 2004  
Fishing

High Water Temperature In Grande Ronde Kills 239 Adult Spring Chinook  
Columbia Basin Bulletin, August 14, 2009 (PST)



## ESA Listed Species

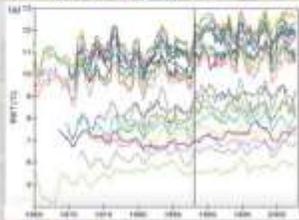
## Land Use & Water Development



# Brown Trout Populations in Switzerland

## Trends from 1978-2002

### Stream Temp Increases



Year

### Disease Outbreaks

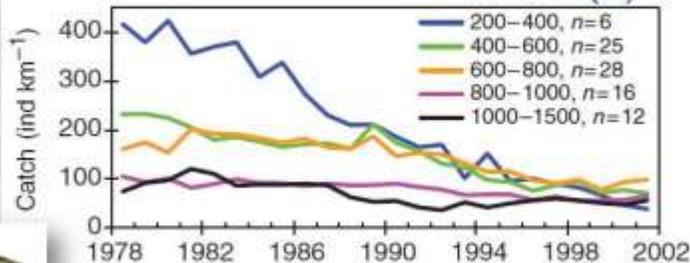


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Populations declining faster in warm streams

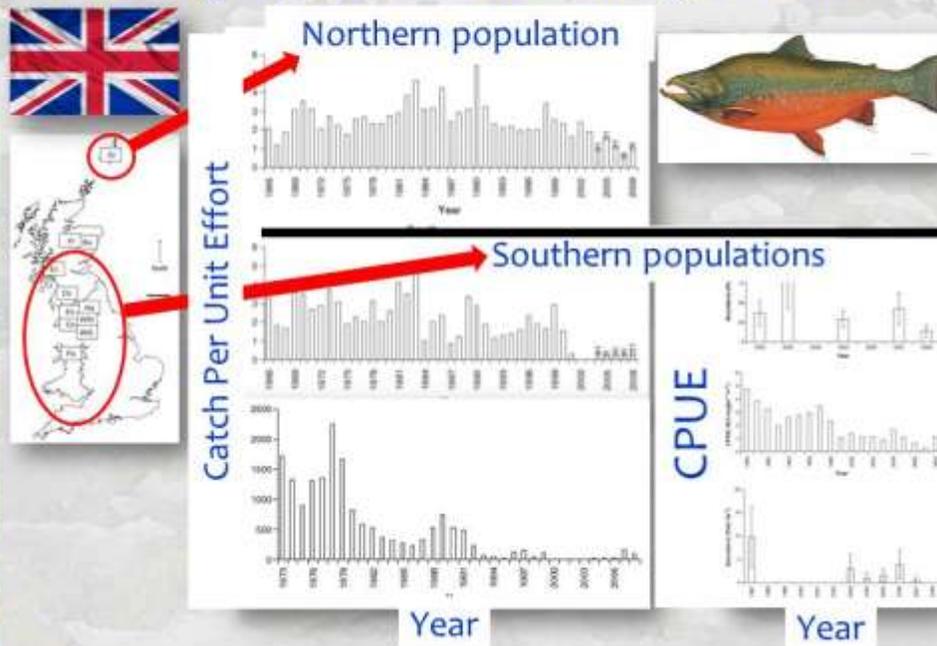
Elevation (m)



Hari et al. 2006. *Global Change Biology* 12:10-26.

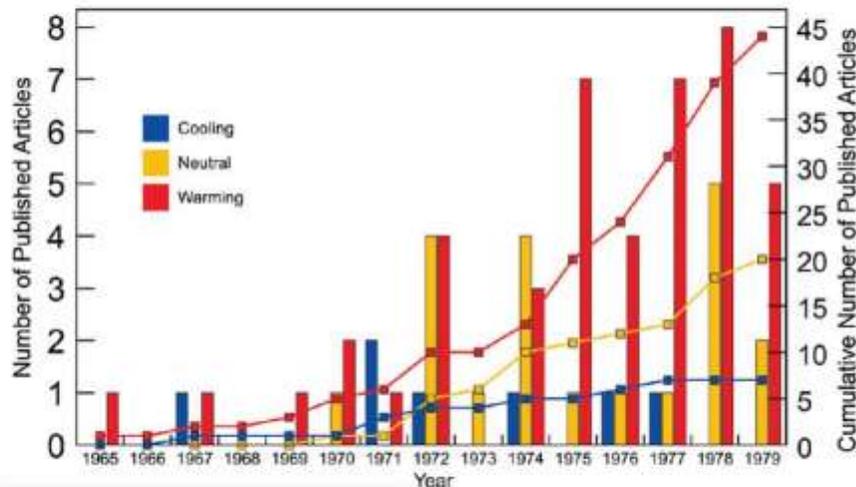
# Arctic Char Lake Populations in the U.K.

Declining Fastest at Southern Range Extent



Winfield et al. 2010. *Hydrobiologia* 650:55-65.

# Models Predicting Global Warming Emerged as the Scientific Consensus ~40 Years Ago...

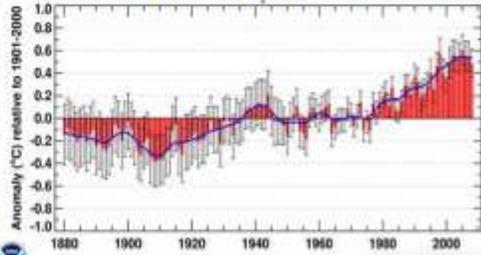


THE MYTH OF THE 1970s GLOBAL COOLING SCIENTIFIC CONSENSUS

Peterson et al. 2008. *Bull. Amer. Metero. Soc.* 89:1325-1337.

# Subsequent Measurements Have Provided Empirical Support for Model Predictions & Improvements

### Global Air Temperature Trend



### U.S. Air Temperature Trends 1970 - 2011



Great Interactive WebTool

CLIMATE CENTRAL

<http://www.climatecentral.org/news/the-heat-is-on/>



Welcome to the Climate-Aquatics Blog. For those new to the blog, previous posts with embedded graphics can be seen by clicking on the hyperlinks at the bottom or by navigating to the blog archive webpage on our Forest Service site at: ([http://www.fs.fed.us/rm/boise/AWAE/projects/stream\\_temp/stream\\_temperature\\_climate\\_aquatics\\_blog.html](http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/stream_temperature_climate_aquatics_blog.html)). To discuss these topics with other interested parties, a Google discussion group has also been established and instructions for joining the group are also on the webpage. The intent of the Climate-Aquatics Blog and associated discussion group is to provide a means for the 4,538 (& growing) field biologists, hydrologists, anglers, students, managers, and researchers currently on this mailing list across North America, Europe, and Asia to more broadly and rapidly discuss topical issues associated with aquatic ecosystems and climate change.

Messages periodically posted to the blog will highlight new peer-reviewed research and science tools that may be useful in addressing this global phenomenon. Admittedly, many of the ideas for postings have their roots in studies I and my colleagues have been a part of in the Rocky Mountain region, but attempts will be made to present topics & tools in ways that highlight their broader, global relevance. Moreover, I acknowledge that the studies, tools, and techniques highlighted in these missives are by no means the only, or perhaps even the best, science products in existence on particular topics, so the hope is that this discussion group engages others doing, or interested in, similar work and that healthy debates & information exchanges will occur to facilitate the rapid dissemination of knowledge among those most concerned about climate change and its effects on aquatic ecosystems.

If you know of others interested in climate change and aquatic ecosystems, please forward this message and their names can be added to the mailing list for notification regarding additional science products on this topic. If you do not want to be contacted regarding future such notifications, please reply to that effect and you will be removed from this mailing list.

#### Previous Posts

##### Climate-Aquatics Overviews

Blog #1: [Climate-aquatics workshop science presentations available online](#)

Blog #2: [A new climate-aquatics synthesis report](#)

##### Climate-Aquatics Thermal Module

Blog #3: [Underwater epoxy technique for full-year stream temperature monitoring](#)

Blog #4: [A GoogleMap tool for interagency coordination of regional stream temperature monitoring](#)

Blog #5: [Massive air & stream sensor networks for ecologically relevant climate downscaling](#)

Blog #6: [Thoughts on monitoring air temperatures in complex, forested terrain](#)

Blog #7: [Downscaling of climate change effects on river network temperatures using inter-agency temperature databases with new spatial statistical stream network models](#)

Blog #8: [Thoughts on monitoring designs for temperature sensor networks across river and stream basins](#)

Blog #9: [Assessing climate sensitivity of aquatic habitats by direct measurement of stream & air temperatures](#)

Blog #10: [Long-term monitoring shows climate change effects on river & stream temperatures](#)

Blog #11: [Long-term monitoring shows climate change effects on lake temperatures](#)

- Blog #12: [Climate trends & climate cycles & weather weirdness](#)
- Blog #13: [Tools for visualizing local historical climate trends](#)
- Blog #14: [Leveraging short-term stream temperature records to describe long-term trends](#)
- Blog #15: [Wildfire & riparian vegetation change as the wildcards in climate warming of streams](#)
- Blog #23: [New studies describe historic & future rates of warming in Northwest US streams](#)
- Blog #24: [NoRRTN: An inexpensive regional river temperature monitoring network](#)
- Blog #25: [NorWeST: A massive regional stream temperature database](#)
- Blog #26: [Mapping thermal heterogeneity & climate in riverine environments](#)

#### Climate-Aquatics Hydrology Module

- Blog #16: [Shrinking snowpacks across the western US associated with climate change](#)
- Blog #17: [Advances in stream flow runoff and changing flood risks across the western US](#)
- Blog #18: [Climate change & observed trends toward lower summer flows in the northwest US](#)
- Blog #19: [Groundwater mediation of stream flow responses to climate change](#)
- Blog #20: [GIS tools for mapping flow responses of western U.S. streams to climate change](#)
- Blog #21: [More discharge data to address more hydroclimate questions](#)
- Blog #22: [Climate change effects on sediment delivery to stream channels](#)

#### Climate-Aquatics Cool Stuff Module

- Blog #27: [Part 1, Spatial statistical models for stream networks: context & conceptual foundations](#)
- Blog #28: [Part 2, Spatial statistical models for stream networks: applications and inference](#)
- Blog #29: [Part 3, Spatial statistical models for stream networks: freeware tools for model implementation](#)

#### Climate-Aquatics Biology Module

- Blog #30: [Recording and mapping Earth's stream biodiversity from genetic samples of critters](#)
- Blog #31: [Global trends in species shifts caused by climate change](#)
- Blog #32: [Empirical evidence of fish phenology shifts related to climate change](#)
- Blog #33: [Part 1, Fish distribution shifts from climate change: Predicted patterns](#)

#### Future topics...

#### Climate-Aquatics Management Module