Climate-Aquatics Blog #32: Empirical evidence of fish phenology shifts related to climate change

Are Fish Like Flowers?

Hi Everyone,
The answer to the question is probably not in most regards, but perhaps so with their response to climate change. Recall that last time we highlighted the Parmesan and Yohe review study describing the global rates at which species distributions have been shifting poleward and life history phenologies accelerating as global warming proceeds (graphic 1; blog #31). This time we're examining the empirical evidence for the latter in fish populations, because unfortunately, none of the 1,700 species Parmesan and Yohe reviewed were freshwater fish.

To see biological associations with climate trends what's usually needed are long-term monitoring records. Maintaining such efforts on shoestring budgets is always a challenge (because it just monitoring data, right?) but these data do exist and have a way of popping up once their importance becomes better appreciated. And as we've seen time and again, these "just monitoring" data often prove invaluable since there's no way to ever go back in time and measure something once we realize later that it's important. As a brief aside, graphic 2 shows the famous atmospheric carbon dioxide monitoring record initiated by Charles Keeling on Mauna Loa in the late 1950's that's been instrumental to understanding this whole global warming business. Without that record (& I'm sure at the time he heard plenty of, "you want to measure what? where? and for how long?!!!") and global air temperature records over the last century, we'd have little insight regarding what's presently afoot with the Earth's climate system.

But back to biology—long-term records—phenologic shifts. The basic idea is that warmer temperatures accelerate metabolic processes, which in turn accelerate growth and development of individuals, so those individuals tend to do things earlier and earlier over time across generations. Intuitively this makes sense—we're all accustomed to seeing flowers bloom at different times in the spring depending on whether it's a warm or cool year; the grass needing to be mowed sooner or later depending on whether it's been a late or early spring; the geese migrating south depending early or late depending on when winter came that year. With climate change, it's the same thing; we're just stretching the time horizon so that the climatic variation occurs as tiny increments each year rather than relatively large, inter-annual changes. And that's why long-term monitoring efforts are needed, that inter-annual "noise" easily swamps the climate trend "signal" that may be there unless we're there for a long time.

So one of the places we've tended to hang around fish for a long time consistently is when they're on or near their spawning grounds and we're either trying to eat them, count them, or capture them to steal their gametes. Kindof creepy if you think about it, but in some instances now we do have good datasets with which to assess long-term trends in fish showing up for their annual harassment. One study based on such a dataset is by Wedekind & Kung in which they describe 60 year trends in the timing of spawning for European grayling in a Swiss lake river outlet (graphic 3). Over that period, the dates at which the first-, median-, and last-reproductively mature females arrived at the spawning ground has steadily advanced at the rate

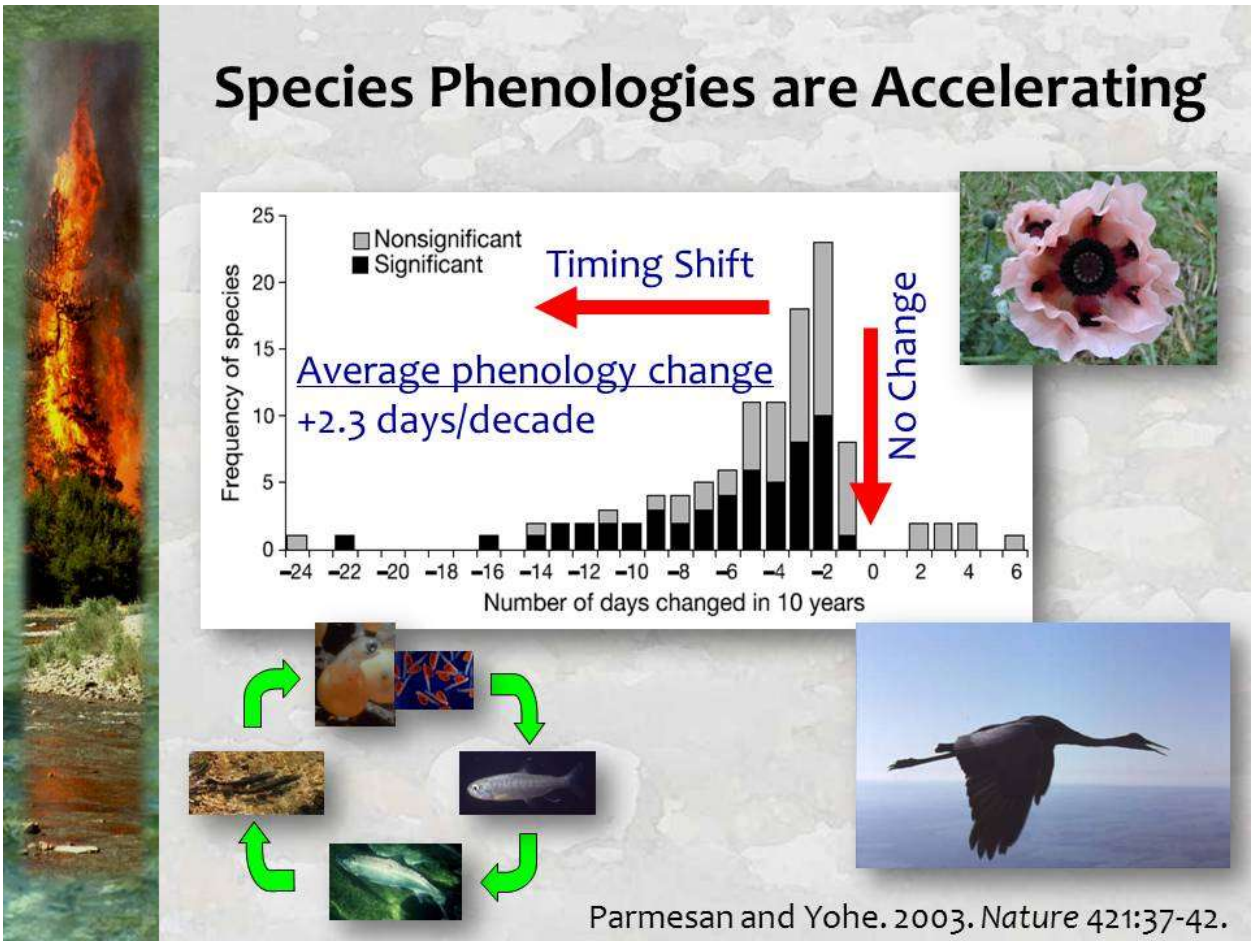
of 6 days/decade so that now the fish are getting busy a full month earlier than they once did. During the 40 year period for which river temperature data were monitored, a clear warming trend was also apparent. In a twist to the normal situation, few nearby air temperature data were available to determine whether this warming trend was indicative of local climate trends, so the authors used the sugar content of grapes from a nearby vineyard as a surrogate for air temperatures. Apparently grapes are more sugary when it's warmer so they track air temperatures. And those same air temperatures drive river temperatures, which drive grayling spawning, so it's all one big ball of wax & maybe fish are like grapes too?

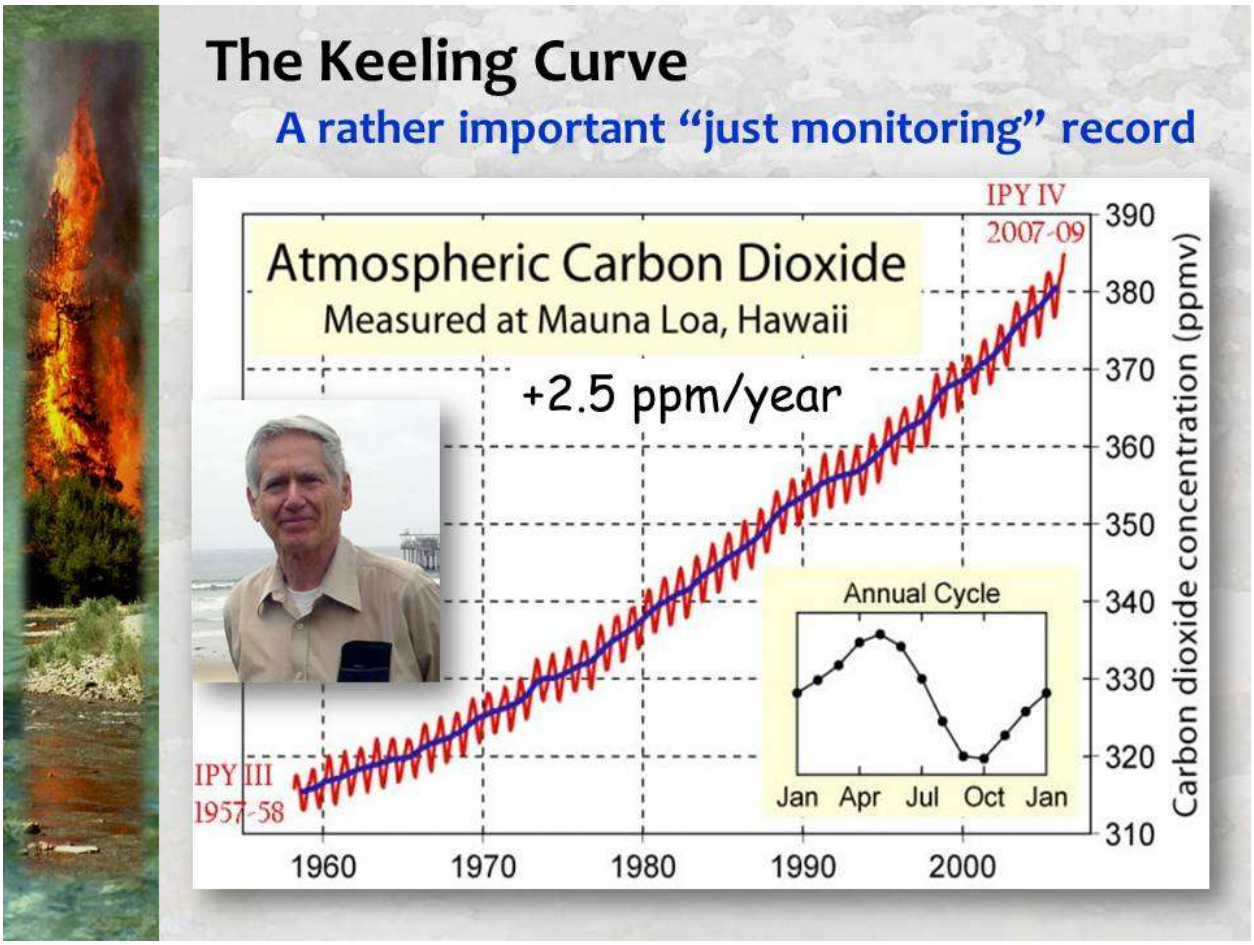
Another place we've long hung around fish are at dams and other impediments we or nature have constructed along the migratory routes some species take to their spawning grounds. Say what you will about dams in terms of their effects on fish populations, but they do sometimes make wonderful weirs & counting facilities, especially when equipped with fish ladders and windows where people sit and count fish all day for decades on end. Talk about a job for a fish voyeur, and talk about some good long-term data! So the second study today by Crozier and colleagues is based on one of these datasets, from Bonneville dam on the Columbia River in the Northwest U.S. Here, sockeye salmon have been counted passing the dam since 1938 and clear trends toward earlier migrations have emerged as temperatures increased during the last 70 years (graphic 4). The authors go beyond simply describing these trends, however, to also develop a technique for assessing the relative roles of phenotypic plasticity and genetic changes in causing the migration trend. They argue that a significant portion of the trend could be due to genetic changes forced by the selective gradient that temperature increases are causing. If that's the case, it's not just that fish are plastic and are shifting their timing, but they may also slowly be becoming different fish through evolutionary processes.

What a great example of how good monitoring data can feed directly into powerful science & facilitates the development and testing of theory. I wish we were running climate-aquatics experiments in different ways this century that didn't risk so much biodiversity, but it is what it is. A non-stationary climate will provide many such natural experiments that allow us to learn a great deal about ecology and biophysical relationships if we're watching the right things in the right places for a long time.

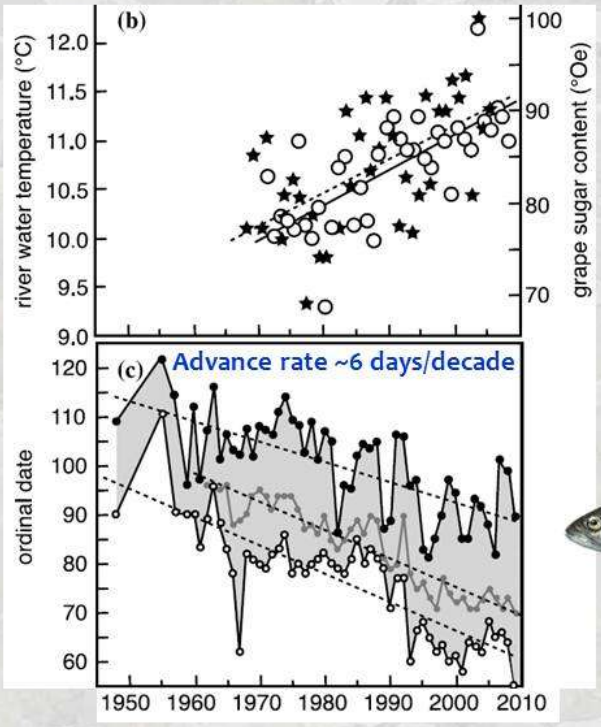
Until next time, best regards,

Dan


Species Phenologies are Accelerating
Nonsignificant
Significant
Timing Shift
No Change
Average phenology change
+2.3 days/decade
Frequency of species
Number of days changed in 10 years
Parmesan and Yohe. 2003. Nature 421:37-42.

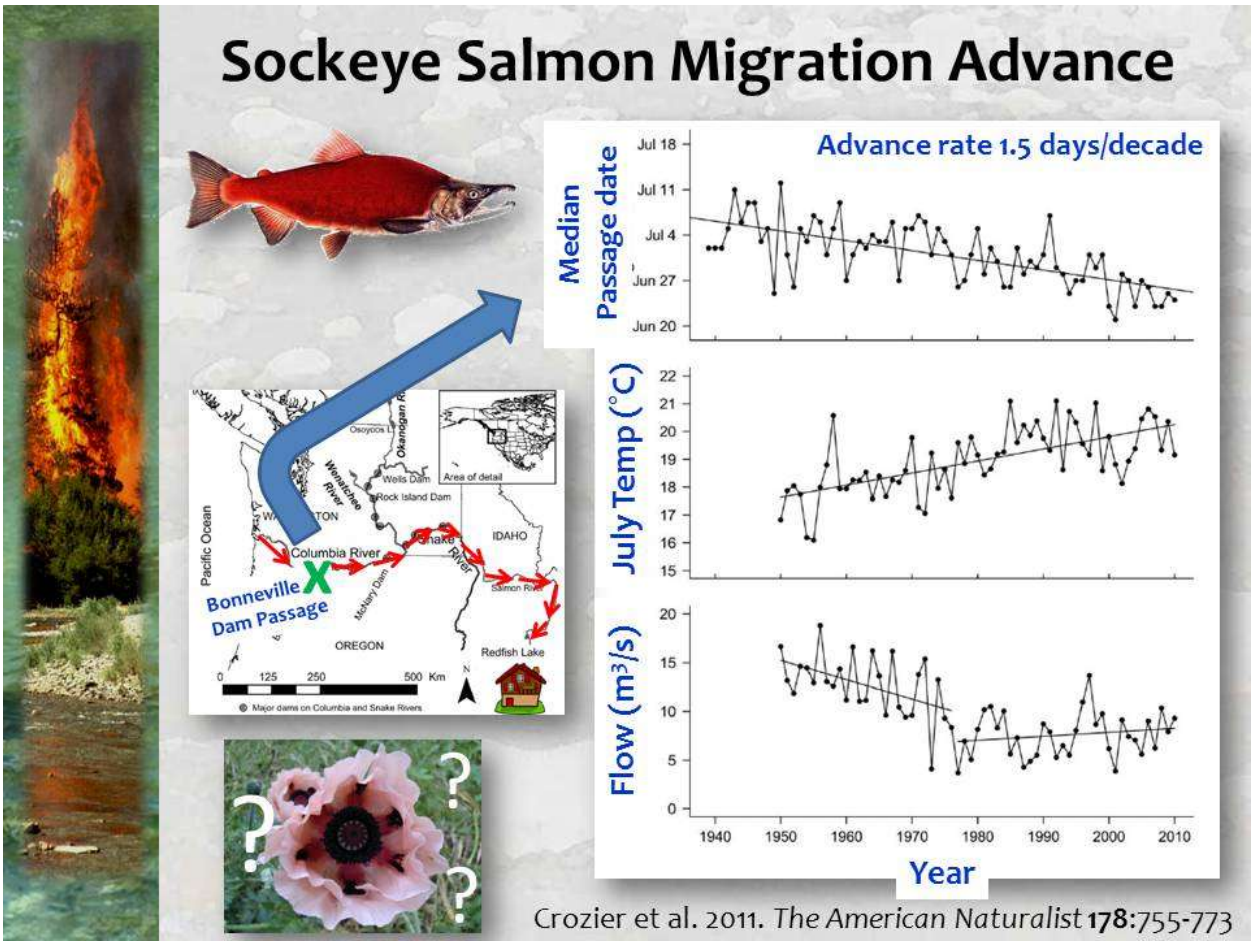

The Keeling Curve
A rather important "just monitoring" record
Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
+2.5 ppm/year
IPY IV
2007-09
IPY III
1957-58
Annual Cycle
Jan Apr Jul Oct Jan
390
380
370
360
350
340
330
320
310
1960
1970
1980
1990
2000
Carbon dioxide concentration (ppmv)

European Grayling Spawning Advance



... or maybe they're more like grapes?

Wedekind & Kung. 2010. *Conservation Biology* **24**:1418-1423



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). 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

Future topics…
Climate-Aquatics Management Module