Here are some frequently asked questions (and answers!) about climate change and their impacts to coldwater fish resources. The following is divided into four sections: general climate change, impacts to trout and salmon, impacts to landscapes and rivers, and getting involved.

General Climate Change

HOW DO SCIENTISTS MONITOR CLIMATE, AND WHAT EVIDENCE IS THERE THAT IT IS CHANGING?

Air temperatures around the globe are monitored by NASA's Goddard Institute for Space Studies, NOAA and others. Global temperatures have increased steadily since the beginning of the industrial revolution. The longest continually running data set is maintained by NASA and dates back to 1880 as shown below. According to the NASA data, which is consistent with NOAA and other records, 16 of the 17 warmest years in the 136-year record have occurred since 2001. 2016 was the hottest year on record, which broke the previous record high annual temperature average established in 2015. The average global air temperature is about 1°C or about 1.8°F warmer as compared to the 1951-1980 average.

Global air temperature anomaly as compared to the base of 1951 to 1980. Data from NASA's Goddard Institute for Space Studies

WHAT IS CAUSING THE INCREASE IN AIR TEMPERATURE?

Sunlight passes through the atmosphere and warms the Earth's surface. Heat is then radiated upward from the Earth's surface where it is trapped by greenhouse gas molecules that act like an atmospheric blanket. These molecules consist primarily of carbon dioxide (CO_2) but also methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O). Increasing amounts of greenhouse gases, especially CO_2 and to a somewhat lesser extent CH_4, are being produced by the burning of fossil fuels and oil and gas production. These additional molecules then act like a thicker blanket that traps more of the sun's heat energy underneath it. The longest record of direct measurements of CO_2 has been conducted at the Mauna Loa Observatory in Hawaii. These measurements began in March 1958 by Scientists at Scripps Institution and show the dramatic increase in CO_2 concentration from less than 320 ppm in the late 1950s to more than 400 ppm in 2016 and 2017 (May 2016 average of 407.70; May 2017 average of 409.65 ppm). NASA has directly measured the energy output of the sun since 1978 and detected a very slight drop in solar irradiance. So, changes in solar output do not appear to be responsible for the observed changes in temperature.

CAN INDIVIDUAL EXTREME WEATHER EVENTS BE ATTRIBUTED TO CLIMATE CHANGE?

Generally speaking, weather refers to the daily conditions of heat, dryness, rain, wind or other events like tornados, whereas climate is the longer term pattern and trend of weather conditions. Thus, a single high intensity summer rainfall event or a single warm winter day does not by itself signify that the climate is changing, but the increasing frequency of such extreme events over time is evidence of climate change. The connection between longer-term climate change and extreme weather has been an increasing area of scientific study over the past decade. Increasing heat or energy in our atmosphere will increase the intensity of large storm events but understanding which events can be attributed to climate change is challenging given the natural variation in weather. Increasing evaporation from higher temperatures also leads to extreme drought but more moisture in the air can lead to heavier rainfall and snowfall events. In 2016 the National Academy of Sciences (NAS) released a report that summarized the science of attributing extreme weather events in the context of climate change. According to the NAS,

our confidence in attributing extreme weather events to changing climate is greatest for those events related to changes in temperature, including extreme cold or extreme heat. Drought and heavy rainfall events are strongly influenced by temperature, so also have relatively high relationship to climate change. Changes in atmospheric circulation and dynamics are less directly controlled by temperature so events like hurricanes and tornadoes are less clearly connected to temperature changes.

DO 97% OF SCIENTISTS REALLY BELIEVE THAT CLIMATE CHANGE IS HUMAN CAUSED?

A 2009 study reported in Earth and Space Science News showed that 97.5% of climate scientists that actively study climate change believe that it is human caused. Slightly less than 90% of climatologists not currently active in climate change research believe that humans are causing climate change.

Impacts to Trout and Salmon

WHAT ARE THE PREDICTED IMPACTS TO BULL TROUT FROM CLIMATE CHANGE?

Because bull trout require very cold water for spawning and rearing, researchers from the U.S. Forest Service predicted that up to 92% of natal bull trout habitat could be lost due to climate change.

HAS ANYONE ACTUALLY DOCUMENTED DECLINES IN BULL TROUT DUE TO CLIMATE CHANGE?

From 2009 to 2011 scientists at the University of Montana and U.S. Forest Service re-surveyed portions of the Bitterroot River in Montana and found that bull trout had already abandoned low-elevation habitats with warm temperatures where the species was present in the early 1990s.

HOW IS CLIMATE CHANGE EXPECTED TO IMPACT OTHER TROUT SPECIES?

Cutthroat trout, rainbow trout, brook trout, and brown trout habitat is predicted to decrease by about 50 to 75% in the interior western U.S. by the 2080s due to changes in temperatures, hydrology, and interactions with non-native trout according to a study by Trout Unlimited and partner scientists.

WILL CLIMATE CHANGE IMPACT BROOK TROUT TOO?

Scientists with the Wisconsin DNR and USGS projected that brook trout in Wisconsin will decline by about 95% under even moderate climate warming, and Oregon State University, University of Maryland, and Cornell University scientists have shown that increased temperatures delay and reduce brook trout spawning in Adirondack lakes.

WILL CLIMATE CHANGE IMPACT SALMON DIFFERENTLY THAN TROUT?

Unlike most trout, salmon migrate to the ocean, and increased river temperatures can cause migration barriers when salmon return to rivers and streams to spawn. A University of Washington study found that unsuitable temperatures for summer salmon migrations may exist for 10 to 12 weeks during summer by the 2080s in key migration corridors such as the Columbia River. Climate change also is impacting the ocean, where salmon migrate and feed.

IS THE OCEAN GETTING MORE ACIDIC? WILL THAT IMPACT SALMON TOO?

The Ocean is getting more acidic as a result of increasing atmospheric CO2 levels as explained in this American Scientist article. Because salmon spend their adult lives in the ocean, rising ocean temperatures and acidification due to climate change are likely to adversely affect salmon ocean migration patterns and marine food resources. This, in turn, may influence their ability to acquire

adequate energy stores for use during their freshwater spawning migration so they can arrive at natal streams at the correct time for spawning as explained by several scientists from the NOAA, McGill University, and the University of Washington.

Impacts to Landscapes and Rivers

LARGE WILDFIRES SEEM TO BE MORE COMMON THESE DAYS. IS THIS TRUE?

The frequency of large wildfires (>1000 acres) increased across much of the western U.S. from the 1980s to the 2010s, and this increase corresponded with decreasing snowpack, an increase in drought frequency, warmer springs, and earlier forest drying according to researchers at the University of Utah and University of California-Berkeley. In some areas, wildfires also have increased because of past management activities that have increased the abundance of smaller, fire-prone trees.

HOW WILL CLIMATE CHANGE IMPACT SNOWPACK THAT IS IMPORTANT TO COLDWATER STREAMS AND RIVERS?

Canadian and U.S. climate scientists reported a 10-20% loss in snowpack in the western United States between the 1980s and 2000s. That same study projected up to 60% more snowpack could be lost in the next 30 years if climate continues to warm as predicted.

HAVE STREAMFLOWS DECLINED DUE TO THE OBSERVED REDUCTION IN SNOWPACK AND EARLIER RUNOFF?

Forest Service researchers in the Pacific Northwest showed that dry years became drier from 1948 to 2006 and that streamflows during dry years were getting lower as a result, a trend that is expected to continue. Peak streamflows occur earlier in the year, which affects the timing of aquatic insect emergence and fish spawning runs. Researchers from Cornell University found that mayflies emerge earlier as a result of earlier snowmelt and that these mayflies were smaller and females had fewer eggs than if the insects emerged at later dates.

HOW WILL DECLINES IN SUMMER STREAMFLOWS INFLUENCE STREAM TEMPERATURES?

Forest Service scientists also showed that northwestern U.S. stream temperatures have increased by about 0.3°F per decade since 1980, with about half of that change due to warming air temperatures and the other half because of declining streamflows.

WHAT EVIDENCE IS THERE FOR INCREASED RAINFALL INTENSITY AND FLOODING DUE TO CLIMATE CHANGE?

Extreme precipitation and flood events have increased across much the U.S. in the last 50 years, particularly in the Northeast during summer, according to one study by more than 20 U.S. climate scientists.

Getting Involved

WHAT CAN ANGLERS DO TO COMBAT CLIMATE CHANGE IMPACTS TO COLDWATER STREAMS AND RIVERS?

Healthy watersheds are resilient watersheds, and a multitude of restoration actions can improve watershed resiliency and buffer against climate change impacts, as highlighted recently by Trout Unlimited scientists.

WHAT CAN ANGLERS DO TO MINIMIZE STRESS TO TROUT AND SALMON DURING DROUGHT AND EXTREME HEAT?

When temperatures rise, fish may already be stressed, so fish in the morning, retrieve fish quickly, keep'em wet when landing and photographing them, and halt fishing if water temperatures exceed 70°F. See this primer on fish stress by Trout Unlimited scientists.

HOW CAN I CHANGE MY LIFESTYLE TO MINIMIZE MY IMPACT ON THE CLIMATE?

Personal choices from the food you eat, to the vehicles you drive, to your home you and your family live in all add (or subtract) to the causes of climate change. Lifestyle choices make a big difference as described in this article by TU scientists and colleagues. In addition to changing our lifestyles, all of us need to reach out to local and national political leaders and seek policies that reduce the impacts of climate change and the quantities of greenhouse gases in the atmosphere.