Air temperatures around the globe have increased significantly in recent years. According to the Intergovernmental Panel on Climate Change’s latest report (IPCC), “Each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since 1850. The period from 1983 to 2012 was very likely the warmest 30-year period of the last 800 years in the Northern Hemisphere… and likely the warmest 30-year period of the last 1400 years”. The U.S. is no exception to these trends. “U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The most recent decade was the nation’s warmest on record” (Fig 1).

Fig 1. Across the U.S., temperatures have increased steadily since 1900.
INCREASING TEMPERATURE AND DROUGHT: A TOUGH COMBINATION

For many parts of the western U.S., drought and increasing air temperature are spelling trouble for trout. Many rivers like the Madison approach stressful temperatures more frequently (Fig 2). Further south, TU biologists experience stream drying before their eyes in Lahontan cutthroat trout territory (Fig 3). Habitat for the Rio Grande cutthroat trout is being hit particularly hard by drought. According to recent surveys by scientists at the US Geological Survey and New Mexico State University, nearly two-thirds of remaining Rio Grande cutthroat trout populations in Colorado and New Mexico survive in streams with baseflows of less than 1 cfs.3 Stream habitats are literally disappearing as extreme and persistent drought grips the region.

GLACIERS

Glaciers are disappearing across the West, and with them, the cold meltwater on which native trout such as bull trout and westslope cutthroat depend. At the current melt rate, glaciers will have disappeared from Glacier National Park by 2030, which will directly affect downstream fisheries (Fig 4a & 4b). Bull trout are responding by moving upstream.4

DRYING FORESTS & WILDFIRE

Since the mid-1980s as forests have dried and tree mortality has increased5, there has been a marked increase in the duration and intensity of wildfires in the western U.S.6 A recent study7 estimates “human caused climate change contributed to an additional 4.2 million ha of forest fire area during 1984–2015, nearly doubling the forest fire area expected in its absence”. While fire is a natural part of the western ecosystem in which fish have evolved, populations already affected by multiple human-induced stressors (barriers to movement, degraded habitats, non-native species) are less equipped to handle this changing environment.

Wildfires have been a common feature in the evolution of southwestern forests, but in recent years, the scope and intensity of wildfires have been unprecedented. In 2012, the Whitewater-Baldy Fire Complex roared through the core of remaining Gila trout habitat in New Mexico and destroyed several populations. Figure 5 shows the perimeter of the Whitewater-Baldy fire and remnant populations of Gila trout (yellow labels) and restored populations (white labels). The Whitewater-Baldy would become the largest wildfire in New Mexico history. In just the previous year, 2011, the Wallow Fire burned more than 841 sq. miles in Arizona and New Mexico, becoming the largest wildfire in Arizona history, and burning significant parts of Apache trout habitat on the Apache-Sitgreaves National Forest.
As global temperatures rise, our oceans are also warming, affecting entire marine ecosystems. Atlantic salmon abundances have declined over the past 30 years and returning fish have increasingly poor body condition, with more “skinny grilse” being observed in recent years8 (Fig 6).

Carbon dioxide emissions are not only warming but also acidifying our oceans. In the Pacific Ocean, the shells of tiny ‘sea butterflies’, or pteropods, which are an essential food source for ocean-migrating salmon, are literally being eaten away by increasingly acidic waters9 (Fig 7). Acidification has also been attributed to recent commercial shellfish recruitment failures in the Pacific Northwest.

### CHANGING BEHAVIORAL & LIFE HISTORY PATTERNS

Many aquatic species time their behaviors and life history patterns in relation to runoff, peak flows and changing water temperature. The timing of aquatic insect emergence, for example, is changing with earlier peak flows as snow melts earlier. The common stream mayfly, *Baetis*, has begun emerging earlier as a result of drought and warming water in Rocky Mountain streams10 (Fig 8). Eastern native brook trout are also showing evidence of climate impacts, with delayed fall spawn-timing and fewer redds being constructed as temperatures increase.11 Studies of salmon species have documented shifts to match changing stream flows and temperatures. A recent study of pink salmon in Alaska documents that average migration time is almost two weeks earlier than 40 years ago.12 Changes in genetic characteristics point to selection against late migrators, suggesting the change is not just behavioral but that this population is actually evolving toward earlier migration timing.

### AN UNCERTAIN FUTURE

While studies such as these give some insights into how fish and other organisms may be able to adapt to climate change, the outlook for most species that depend on coldwater systems is grim. Cutthroat trout across the West, for example, are expected to lose more than 50% of their remaining habitat by 2080.13 The vital question still unanswered is if and how all the necessary moving parts – like flows, temperature, insect emergence and salmon migrations, and thermal tolerance – will come together as the pace of climate change quickens.
A CALL FOR ACTION

One way to address the impacts of climate change is through adaptation projects that increase the resistance and resilience of stream systems. Restoration projects that TU undertakes to restore degraded riparian areas, reconnect fragmented streams, and reduce stressors such as livestock grazing and invasive species help build resilience. Our collaborative work on streams in northern Nevada (Fig 9) is a good example. In California, TU is restoring high-elevation wet meadows and riparian habitats in an effort to keep rainfall at higher elevation for longer periods and reduce the effects of less snowpack. Dam removal in places like the Elwha and Penobscot increase resilience by expanding populations and available habitat. We need more adaptation projects, not only to help our trout and salmon survive rapid climate change but also to buy society time to find more lasting solutions.

REFERENCES

9 Bednaršek, N., and colleagues. 2014. Limacina helicina shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem. Proceedings of the Royal Society B: Biological Sciences on-line.
14 Luce, C., and colleagues. 2012. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. United States Department of Agriculture Forest Service Rocky Mountain Research Station.

Fig 9. BLM monitoring photos of the mainstem Maggie Creek, NV, in 1980 and 2011 show obvious improvements in stream ponding, bank stability and vegetation, all of which have increased water retention and decreased sedimentation. These habitat improvements, largely due to improved grazing practices, and reconnecting the three main tributaries via culvert remediation, have benefited Lahontan cutthroat trout, which can now move throughout the system.