IN HOT WATER:
How Warming Waters are Stressing Fish and the Fishing Industry

Source: Dan D Summers

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Climate Central

CLIMATE CENTRAL

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America's inland streams, the Great Lakes, and coastal waters are heating up—spelling trouble for fish and the nation's $46.1 billion dollar recreational fishing industry.

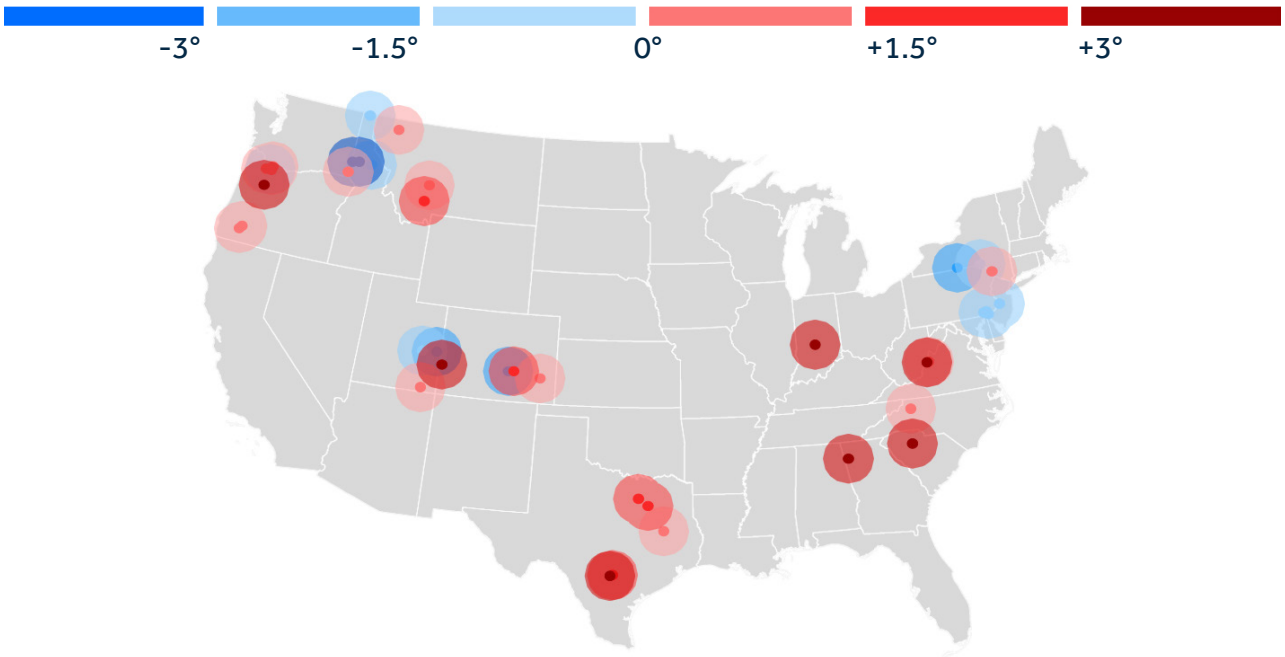
Data analyzed by Climate Central show that water temperatures in the Great Lakes and coastal surface waters are warming throughout the United States, as well as in many freshwater streams. Those warming waters are impacting the health of fish, their ecosystems, and the economies that depend on them.

Many fish are sensitive to temperature and can survive only in specific temperature ranges. As waters in oceans, streams, and the Great Lakes warm, fish seek out cooler waters in higher latitudes or elevation, or when possible, in greater depths. But there are limitations to how far north, or high in elevation, fish can travel before running out of water, let alone water in a suitable temperature zone. Also, water composition changes with rising temperatures. For example, oxygen levels drop and algae blooms grow.

In addition to the direct impacts of hotter water, rising temperatures contribute to more heavy rainfall, which leads to increased runoff that washes pollutants and nutrients into waterways. Warmer winters and earlier springs also result in decreased snowpack, removing a source of cool water to replenish streams, rivers, and lakes in the Western U.S., accelerating the warming of waterways.

River & Stream Temperatures

Change in average temperature since 1990



Change in mean March-August temperature 1990-2018 (°F)
Gauges chosen based on most consistent observational record.
Source: USGS

WARMING WATERS SPELL TROUBLE FOR FISH

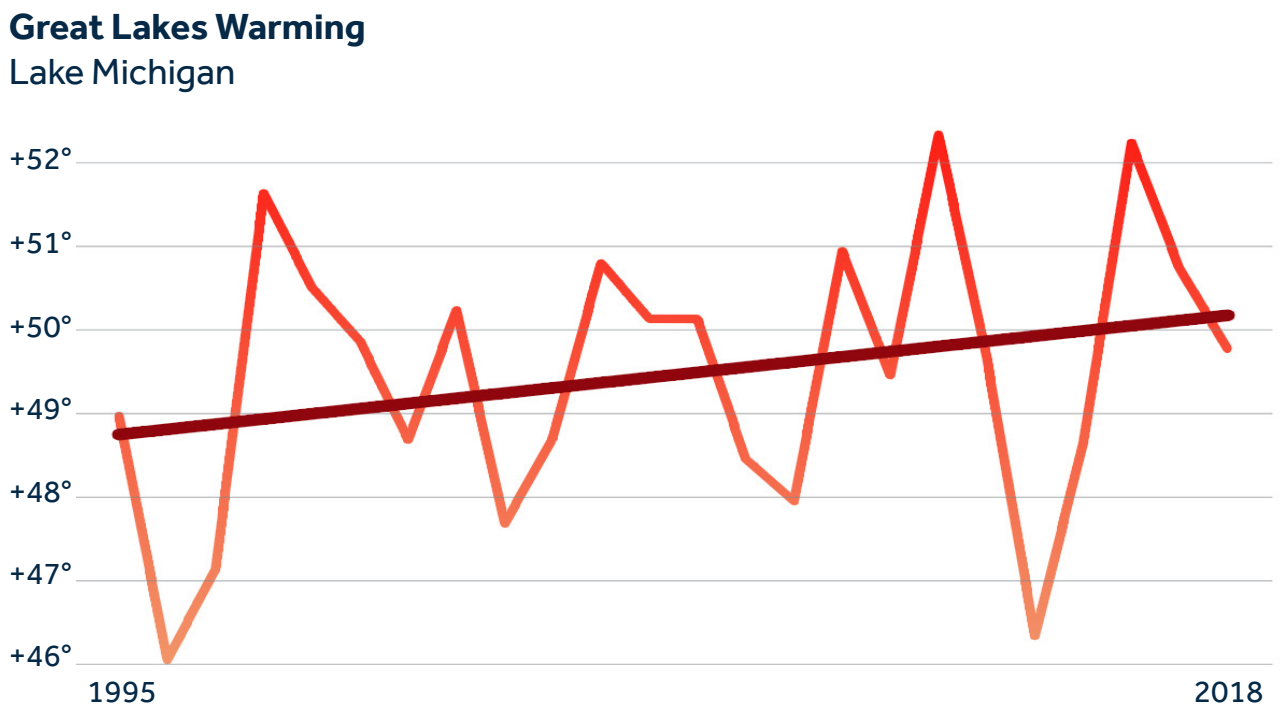
Climate Central analyzed spring and summer stream temperature changes (when water is not frozen) since 1990 at 40 continental U.S gauges operated by the U.S. Geological Survey (USGS). Despite the large number of gauges around the country, only a subset have collected long-term, consistent temperature data over the entire period. Of the gauges analyzed, 65% show an increase in water temperature with that range extending up to as much as 4°F. Among those gauges where there has been a temperature decrease, the drop is as much as 5°F. Rising temperatures are more prevalent in the South and Southeast, with all 10 streams analyzed getting warmer.

Many factors influence stream temperatures, such as water source, stream depth, the density of riparian vegetation around its banks, proximity to any dams, and air temperature that is rising from the increase of greenhouse gases. Water from melted snow will naturally be much colder than runoff from a recent rainstorm, and a dense plant base surrounding the stream will shade the water and keep it several degrees cooler than the water exposed to sunshine.

Warmer waters impact fish in multiple ways. Toxins produced by algae blooms—which are occurring more frequently as temperatures rise—can stress or kill fish by clogging their gills or reducing oxygen levels in the water. Warmer waters also make fish more vulnerable to parasites and diseases. For example, new research shows that a virus which usually infects largemouth bass has also played a role in the decline of smallmouth bass in Pennsylvania's Susquehanna River by weakening their immune systems and allowing other infections to spread. And researchers have found evidence that inland fish are also moving north, changing the timing of migrations and spawning, and altering predator-prey ranges and interactions.

GREAT LAKES

Every Great Lake has warmed since 1995 (when data became available for all lakes). Lake Ontario has recorded the most warming, at 2.2°F. That is followed by Lake Huron at 1.8°F and Lake Erie at 1.7°F. Lakes Superior and Michigan are not far behind, both recording a 1.5°F temperature rise.



Average annual surface water temperature since 1995
Source: NOAA's Great Lakes Environmental Research Laboratory

Sea lamprey (Petromyzon marinus). Credit: T. Lawrence, Great Lakes Fishery Commission.

As the water heats up, fish in the Great Lakes are vulnerable to many of the same problems facing those in streams and oceans: more algae blooms; new species of bacteria, viruses, and other parasites; and northward migration of some species, including large- and smallmouth bass.

One of the region's biggest problems is the parasitic sea lamprey, which invaded the lakes through canals in the 1940s. Warmer water has increased the size and feeding rates of the lamprey, which latch onto and can suck the life out of large Great Lakes fish such as lake trout, brown trout, and lake sturgeon. Continued warming could lead to increased issues, as lamprey thrive at higher temperatures than the fish they prey on.

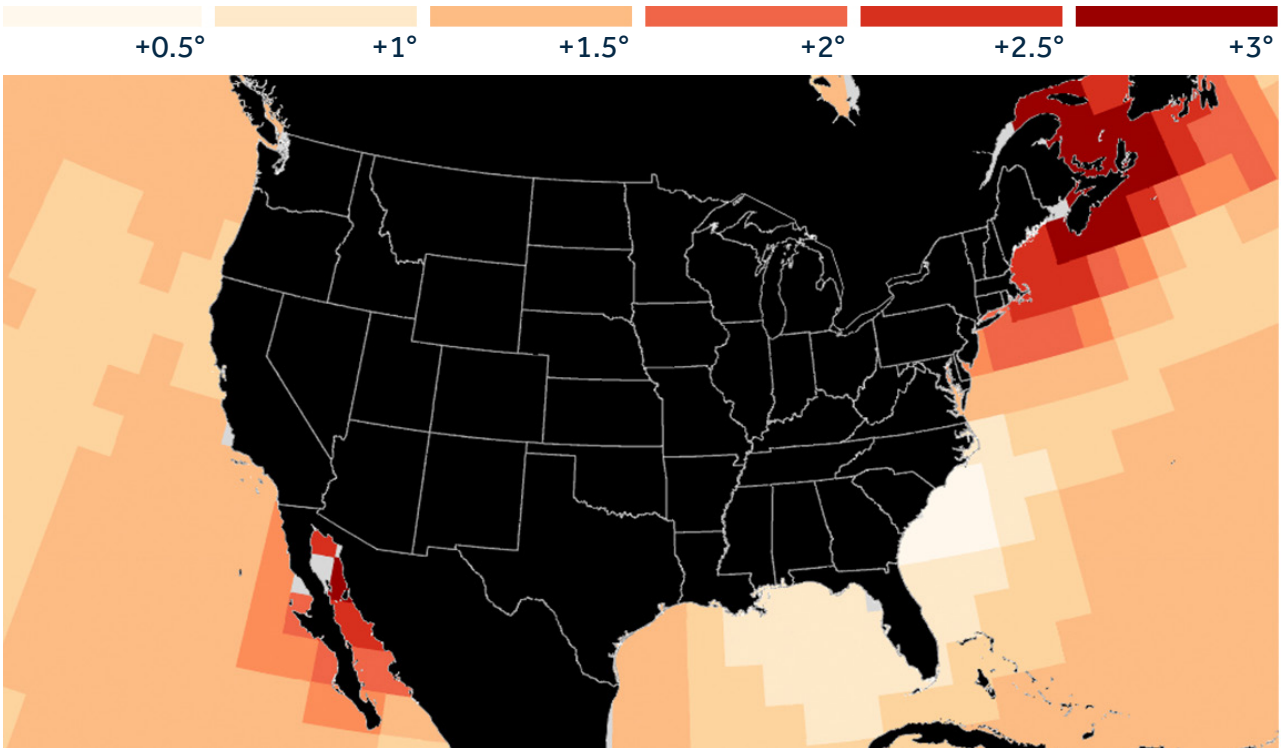
OCEANS

All U.S. coastal surface waters have warmed since 1901. About 93% of the additional heat in the climate system goes into the oceans—and recent research suggests that the oceans are heating up about 40% faster than previously estimated.

Coastal waters off northeastern New England have experienced the greatest warming, up to 3°F. The West Coast has warmed between 1 and 2°F, with southern California coming in at nearly 2oF. Warming along the Gulf of Mexico coastal waters ranges from 0.5 to 2°F, with the Texas Gulf Coast at the higher end of this range and the Florida Gulf Coast at the lower end. Other southern waters of South Carolina and Georgia have notched a relatively modest increase, between 0.1 and 0.4°F).

Ocean Warming

Change in average ocean temperature since 1901



Change in annual sea surface temperatures (°F), 1901-2018. (gray indicates insufficient data)
Source: NOAA Extended Reconstructed Sea Surface Temperature (ERSST) V5 dataset

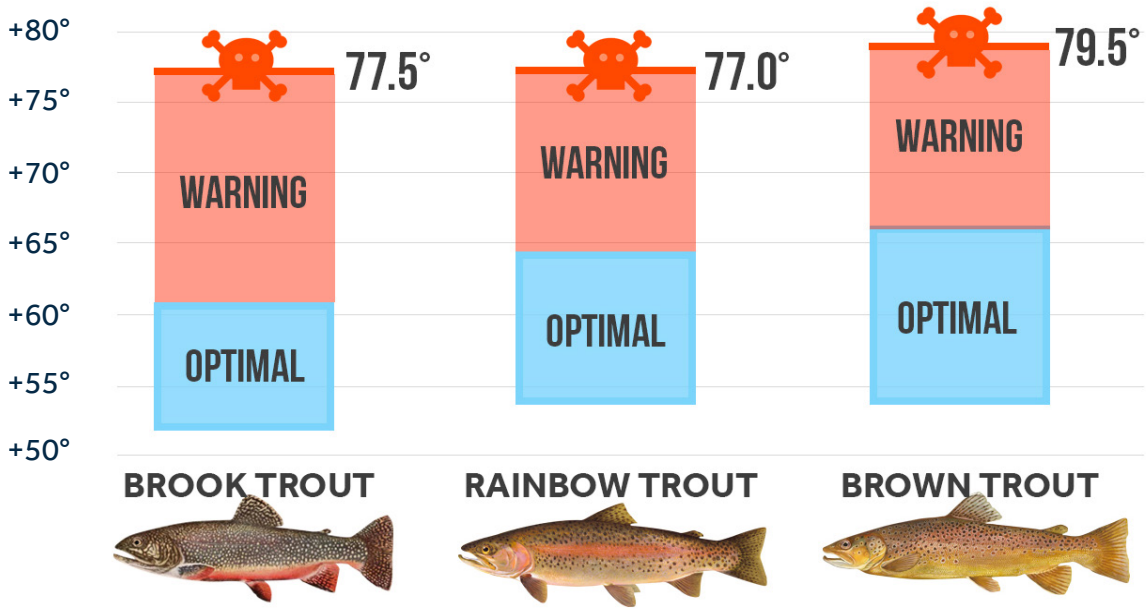
A NOAA Fisheries-funded study found that many fish in U.S. coastal waters are projected to migrate north and move into deeper, cooler waters. Higher ocean temperatures are also a factor in 'Red Tide' algae blooms, which have devastated fish populations and tourist revenue in Florida. And warmer oceans could lead to the loss of billions of marine fish. A study released by the National Academy of Sciences reports that the total mass of sea animals is projected to drop by 5% for every 1.8°F of ocean warming.

A DEEPER DIVE: TROUT, BASS AND SALMON

Trout, bass, and salmon are three of the most popular game fish in the United States. Optimum temperature ranges for three types of each fish family are presented below, which represent the zone where fish really thrive and reproduce. However, as temperatures rise in coastal waterways, lakes, and streams, fish are being pushed into a red zone where they struggle to survive. If they can't migrate to more suitable water—in temperature and composition—then they eventually hit a threshold beyond which they cannot tolerate sustained exposure and die.

Native and introduced geographical ranges are provided in the Appendix.

Warming Out of Range
Trout temperature zones



Source: Morrow, Jr. and Fischenich, 2000

ECONOMIC IMPACTS ON RECREATIONAL FISHING

As warming waters change the habitats and behavior of fish, anglers will struggle to plan fishing trips that connect with fish that are biting, and businesses that relied on previously predictable fishing seasons will need to adapt to increasingly unpredictable revenue streams. Those revenues are big business in the United States.

Every five years the U.S. Fish and Wildlife Service conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, and in 2016, the survey found that $46.1 billion dollars in revenue was generated in recreational fishing-related expenses. Fishing trips were the largest expenditures, generating $21.7 billion, followed by equipment at $21.1 billion and other expenses such as licenses and memberships at $3.3 billion.

Freshwater fishing led the popularity list, generating almost three times more revenue than saltwater fishing—$29.9

billion vs. $11.2 billion. And of the $29.9 billion dollars spent on freshwater fishing, $2.2 billion was spent by anglers in the Great Lakes.

WHAT'S BEING DONE?

The damage that warming waters are causing to fish and the fishing industry is another indication of the urgent need to address climate change. Specific responses to the impacts of warming waters on fish are as varied as the problems that warming causes.

State governments in New York and Montana have restricted or even suspended freshwater fishing when hot weather and high water temperatures are stressing fish.

The Great Lakes Fishery Commission's Lamprey Control Program uses lampricides, traps, barriers, and pheromones and chemical alarm cues to address invasive lamprey populations. And for coastal waters, NOAA has developed regional action plans to guide implementation of their Fisheries Climate Science Strategies. The plans are designed to increase the production, delivery, and use of scientific information to help track changes, assess risks, provide early warnings and forecasts, and evaluate the best management strategies on a regional level.

METHODOLOGY: *To calculate changes in stream temperatures, Climate Central queried over 500 stream gauges to check for temperature data. Only 40 of those gauges had consistent, long-term data, missing no more than 10% of the days each year since 1990. The average water temperature was then estimated for spring and summer (March - August) at the remaining gauges and the temperature change was calculated using the linear slope of these points.*

Great Lakes temperature data is from NOAA's Great Lakes Environmental Research Laboratory. Climate Central calculated the average annual surface water temperature for each lake since 1995. The change in temperature over time was estimated using the linear slope of these points.

Annual average sea surface temperatures from 1901-2018 were analyzed using the NOAA Extended Reconstructed Sea Surface Temperature (ERSST) V5 dataset.

APPENDIX

TROUT

- Brook - Native to the Northeast, Great Lakes, and Mississippi River basins; have been introduced into California, Colorado, Idaho, Montana, and many other states.
- Rainbow- Native to the Pacific Coast and Pacific Northwest; have been introduced into Arizona, Colorado, California, Idaho and many other states.
- Brown - Not native to the US; have been introduced into most states, commonly found in California, Colorado, Montana, New York, Pennsylvania, Wisconsin and Wyoming.

SALMON

- Atlantic - Native to the North Atlantic Ocean basin; have been introduced into the Great Lakes, Puget Sound, California, Idaho and other states.
- Chinook - Native to the Pacific Coast and Pacific Northwest, occasionally strays south to San Diego, California; have been introduced into the Great Lakes, and some East Coast states.
- Pink - Native to the Pacific Coast, occasionally as far south as La Jolla, in southern California; have been introduced into the Great Lakes.

BASS

- Spotted - Native to the Mississippi River basin from southern Ohio and West Virginia to southeastern Kansas, and south to the Gulf; have been introduced into Alabama, Georgia, Missouri, North Carolina and other states.
- Striped - Native to coastal waters along the North American Atlantic Coast and Gulf Coast; have been introduced in California, Texas, and other states.
- Largemouth- Native to most of the central and eastern United States with the exception of Mid-Atlantic and New England states; have been introduced into many states including California, Texas, Montana, North Carolina, Washington.

Geographical ranges: U.S. native and introduced ranges taken from United States Geographical Society. Follow links for maps and details.