How does climate change impact ecosystem processes and what does long-term ecological research add to our understanding of the impacts?

Long-term ecological research on climate ecosystem responses to climate change

Citation Jones, J.A. & Driscoll, C.T. (2022). Long-term ecological research on ecosystem responses to climate change. *BioScience*, 72(9), 814-826. https://doi.org/10.1093/biosci/biac021

How should we think about climate change impacting ecosystem processes on a large scale spatially and temporally?

Climate change impacts ecosystems over large areas and long time-scales. The authors use long term environmental research to create a conceptual framework for assessing how ecosystems respond to climate change and how these responses may differ among ecosystem types, among geographic settings or climatic characteristics, and across ecosystem processes. They discuss the invisible present – the time scale of the impact of our actions, the invisible place – the spatial scale of ecosystem events and processes, and spatiotemporal disturbance dynamics.

How have temperature and moisture changed over time and has the rate of change been constant?

- Most sites warmed over the study period, with the highest rate increases at polar sites and the lowest at tropical sites. The rate of warming increased in the LTER period relative to the 19th century.
- The number of extreme hot months increased and the number of extreme cold months decreased at most sites. The rate of change increased faster during the period of LTER research (1980-2020) than during the 19th century as a whole.
- Two-thirds of the sites with moisture data became functionally wetter during the LTER period.

When are the ecological responses to climate change most prominent?

- Ecosystem responses to climate change are most clear in areas where climate change is most drastic and where climate change results in a phase change of water.

How and when did ecosystem responses differ? Were ecosystem responses influenced by other processes or activities?

- The impacts of climate change on environmental forcing differed among the ecosystem categories. Within categories, the impacts differed among geographic locations.
- Additionally, ecosystem response to climate change varied by core research area and with environmental forcing. The changes in ecosystem response also depended on climate change drivers and human activities.
- Human activities, such as fishing, farming, coastal development, and logging, interact with environmental forcing changes caused by climate change to influence ecosystem processes.

Have climate impacts caused changes in a site's ecosystem category?

- Ecosystem responses to climate change are just beginning to be apparent. So far, climate change has not been linked to major changes in ecosystem type or state at LTER sites.

How can these findings be used to plan for and respond to climate change impacts on ecosystems?

- The broad long-term ecosystem data presented can be used to determine whether ecosystem responses are lagged or cascading through space and time, and can be used to identify cascading disturbances.
- Long-term data can be used to identify processes that work on a long time-scale, such as community composition change, slow succession, and resilience to multiple disturbances.
- This data can also be used to identify the role that spatial distribution of habitat features plays in ecosystem response to climate change and how these responses interact.
- Impacts of climate change are local and research outcomes should be used collaboratively among policy makers and land and resource managers to plan environmental stewardship that is locally relevant.

Research Approach/Methods

- The authors used data from 28 sites in the Western Hemisphere that make up the Long Term Ecological Research (LTER) Network and include ecosystems from Arctic and Antarctic regions to the tropics.
- The researchers divided the 28 sites into four categories: forest and freshwater, dryland, coastal, and marine and pelagic. The sites within each group represent various geographic and climate settings.
- The authors used four time periods, 1930-2020, 1950-2020, the 1980-2020 research period, and 1980-2020 versus the 20th century, to calculate changes in temperature and moisture by habitat group and geographic setting.
- They also consider climate forcing, ecosystem forcing, climate system feedback loops, and ecosystem services.

Keywords environmental forcing, extreme climate events, LTER Network, US National Science Foundation, human activities, ecosystem services

Images

RANK 1

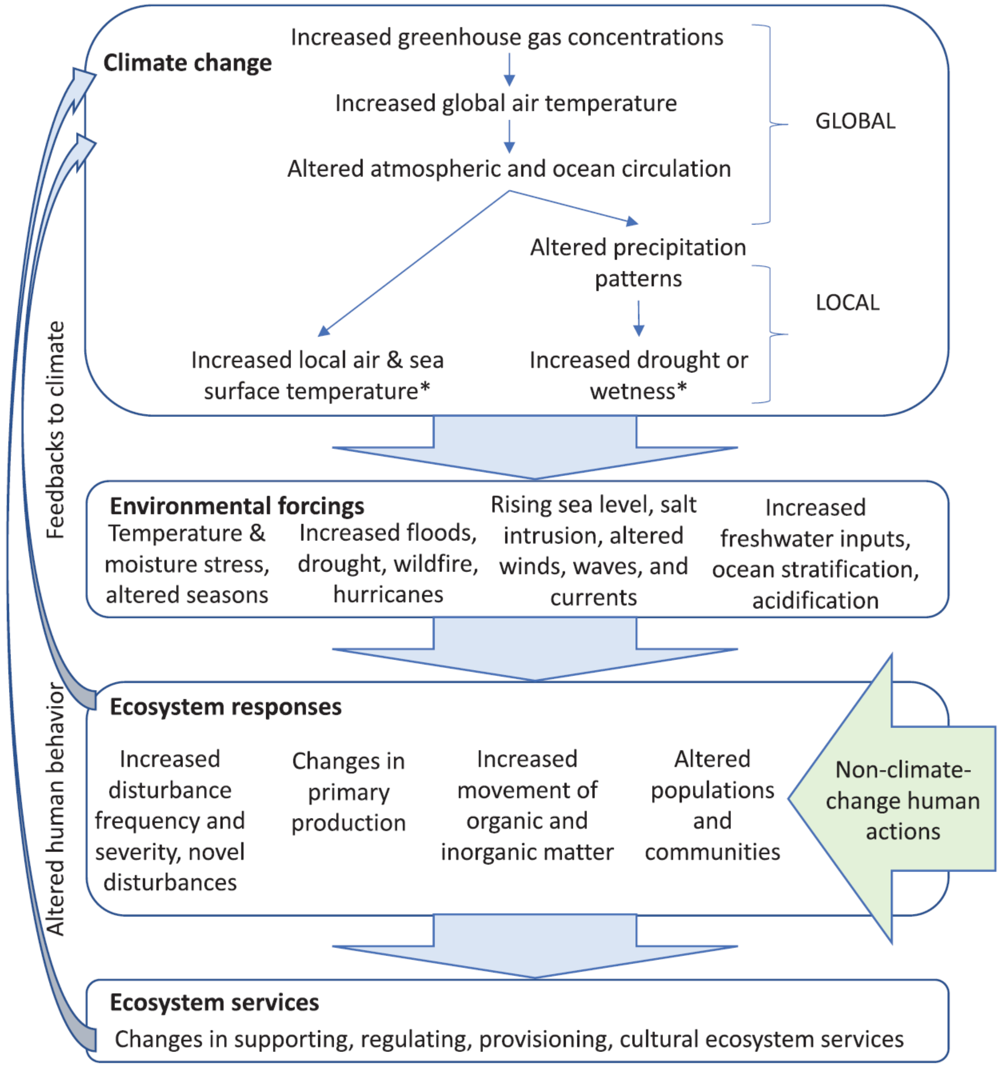

Figure 1 in Jones and Driscoll 2022. Conceptual diagram depicting climate change effects on ecosystem processes at LTER sites addressed in this article and special issue. Global climate change alters local temperature and moisture (*), producing varied types of environmental forcing. Ecosystem processes respond to environmental forcing and to non-climate-change human actions, and these responses affect ecosystem services. Both responses and ecosystem services feed back to climate change.

RANK 2

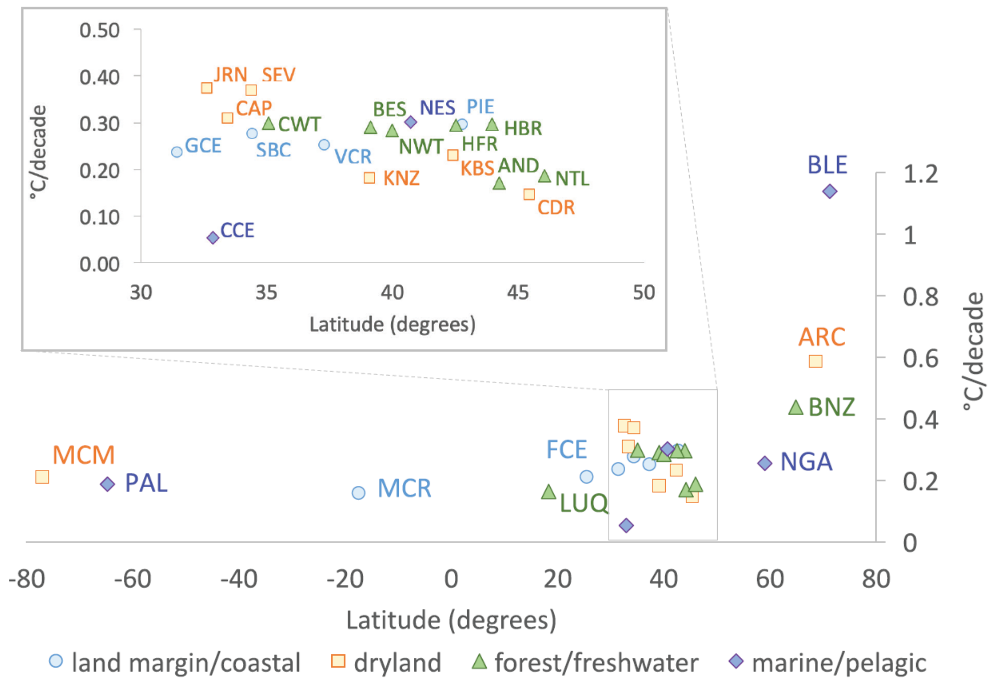

Figure 4 in Jones and Driscoll 2022. Rates of change in temperature from 1980 to 2020 based on Goddard Institute for Space Studies air and sea surface temperature anomalies for LTER sites, by latitude (see the supplemental material for details of data sets and analyses).

RANK 3

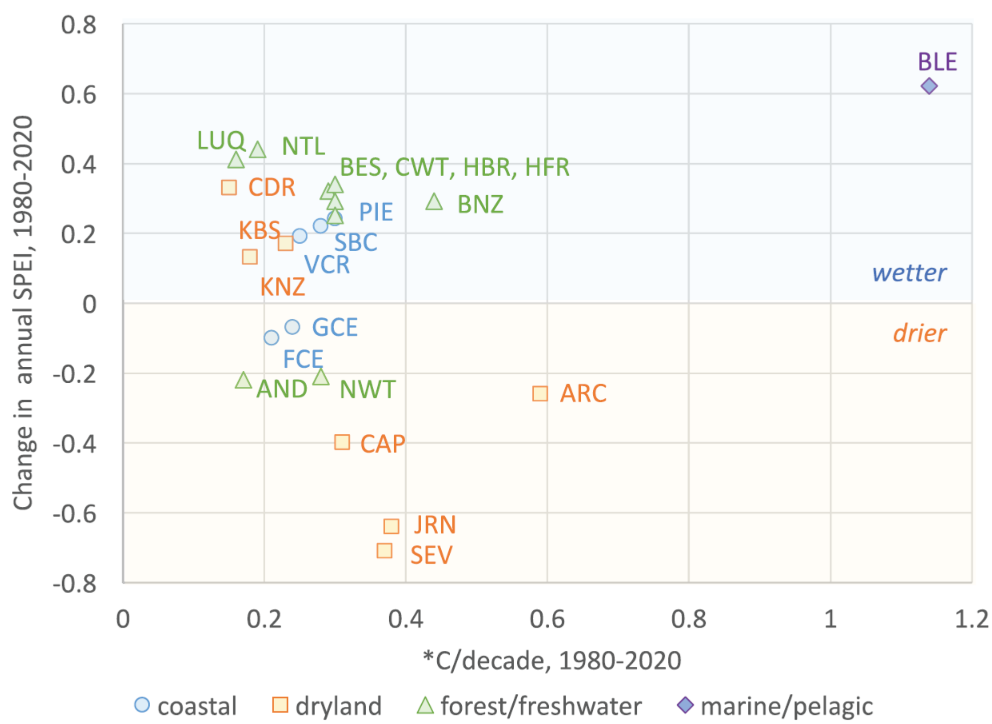

Figure 5 in Jones and Driscoll 2022. Controlling for temperature change, over the LTER period (1980 to 2020), some LTER sites are becoming functionally wetter, whereas others are becoming functionally drier, based on the Standardized Precipitation–Evaporation Index (SPEI; see the supplemental material for details of data and analyses). SPEI data are not calculated for open ocean sites or Antarctic sites (CCE, NES, NGA, MCM, MCR, or PAL). Excluding the Alaska sites, which are all warming faster than the continental US or Puerto Rico, warming rates are higher at sites that have become drier and lower at sites that have become wetter.

RANK 4

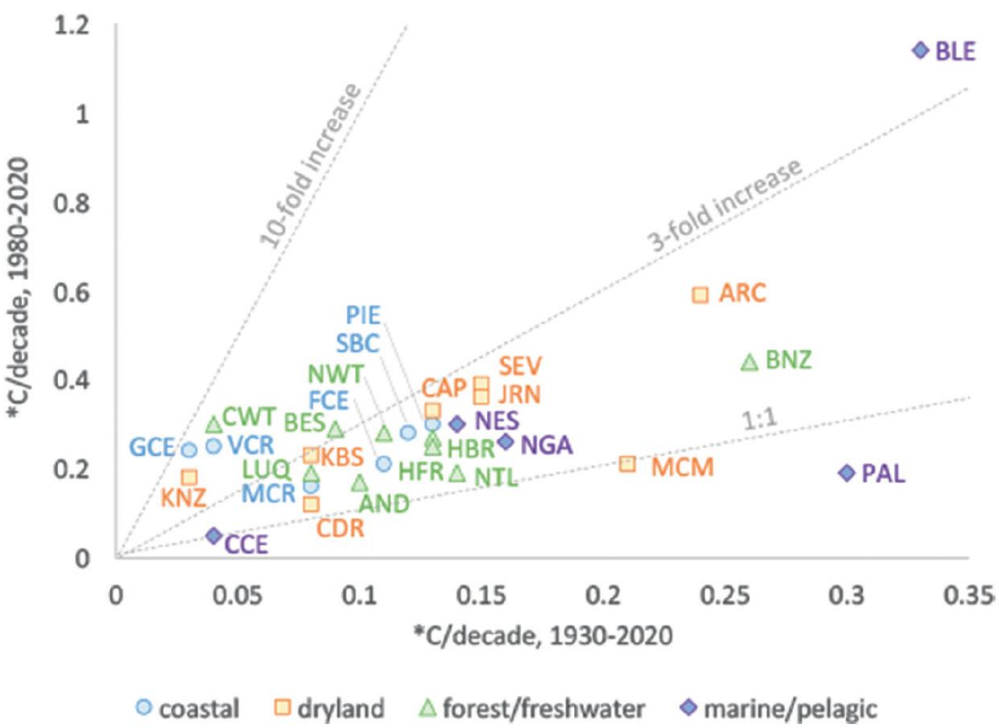

Figure 6 in Jones and Driscoll 2022. The rate of temperature change during the LTER period (1980 to 2020) has accelerated at almost all LTER sites compared to the rate from 1930 to 2020. Warming has accelerated by more than two times and up to ten times. Some sites with relatively low warming rates from 1930 to 2020 have experienced large acceleration in 1980 to 2020.

RANK 5

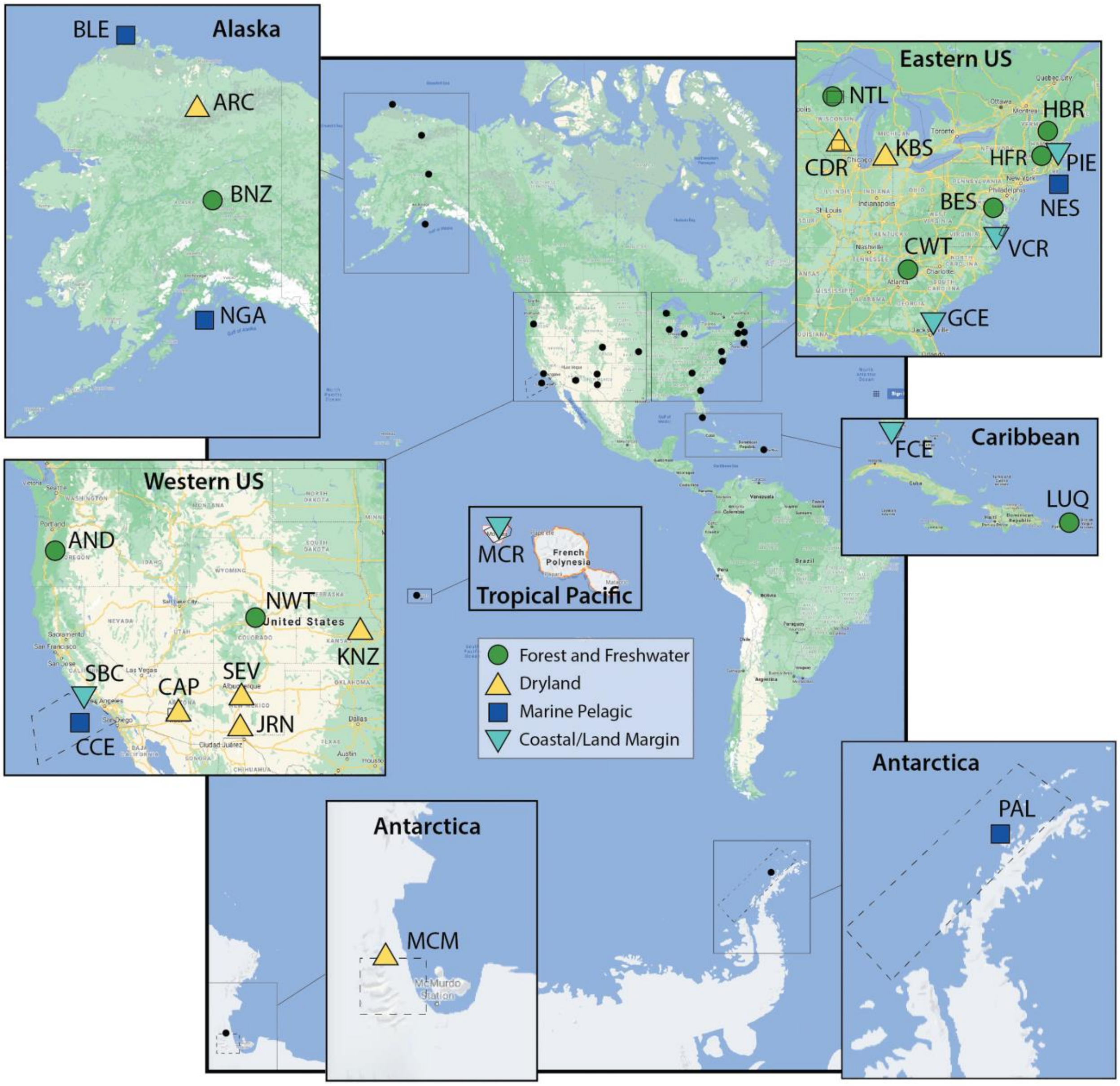

Figure 2 in Jones and Driscoll 2022. Locations of sites in the US Long-Term Ecological Research network, as of 2020, coded by group used in this special issue: marine pelagic, coastal, dryland, forest and freshwater.