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Ecological Significance of Water Temperature

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EnviroDIY
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Stroud Water Research Center

Why is Water Temperature Important?

- Temperature varies temporally and spatially
  - Day versus night
  - Winter versus summer
  - Mountain versus valley
  - Temperate versus tropical (spatial and seasonal)
- Temperature affects rates for chemical reactions
- Chemical reactions affect biological functions, and eventually biological distributions

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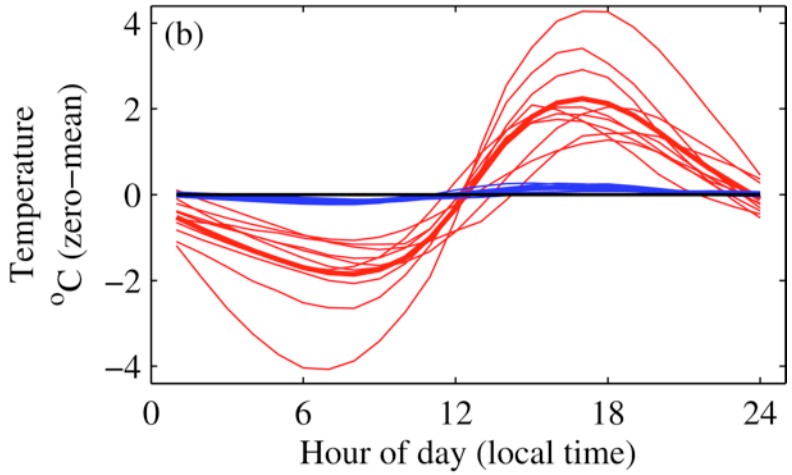
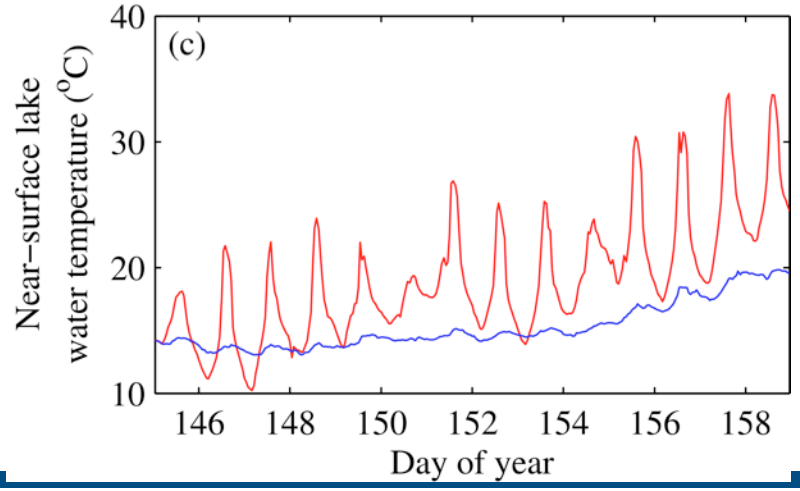
Water Temperature Varies Within a Day





Small lake (red)
versus
Large lake (blue)

Woolway RI, Jones ID, Maberly SC, French JR, Livingstone DM, Monteith DT, et al. (2016) Diel Surface Temperature Range Scales with Lake Size. PLoS ONE 11(3): e0152466. https://doi.org/10.1371/journal.pone.0152466

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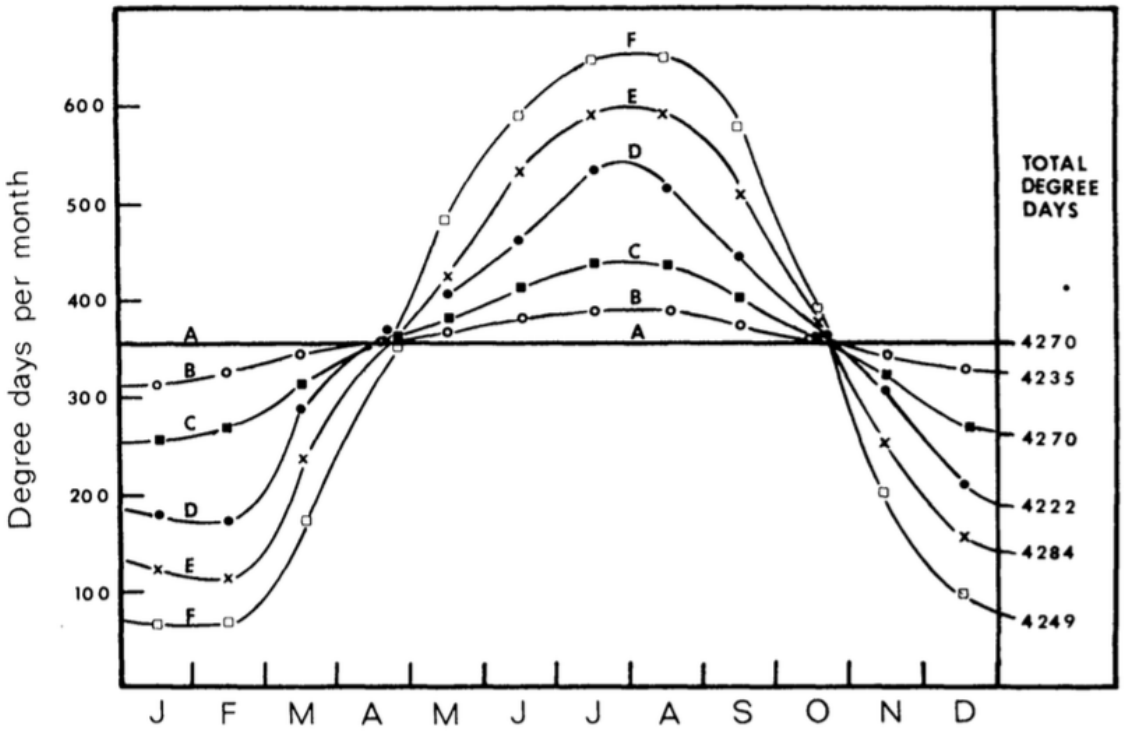
Temperature Varies Seasonally



Winter is Colder Than Summer

FIG. 2.—Distribution of monthly degree-day accumulations at various recording stations along White Clay Creek. Total degree-days are the annual sum of monthly records for each station. *A*, outflow of groundwater; *B*, woodland spring seeps; *C*, first order spring brooks; *D*, second order streams; *E*, third order stream (upstream segment); *F*, third order stream (downstream segment).

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Ground Water Temperature Colder in the North

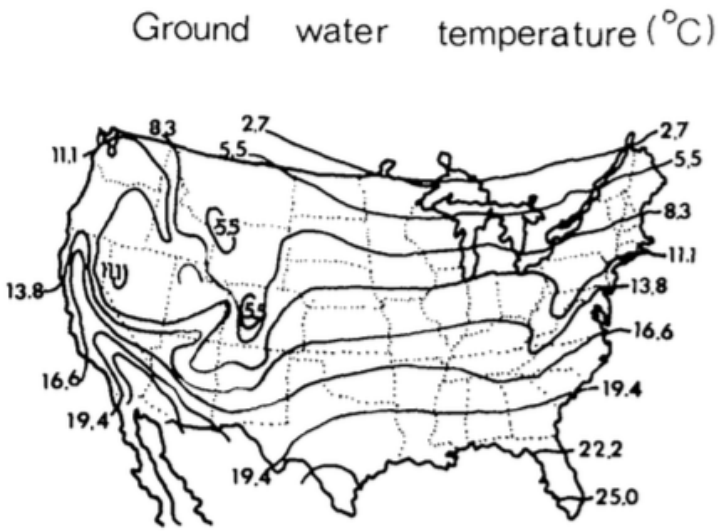
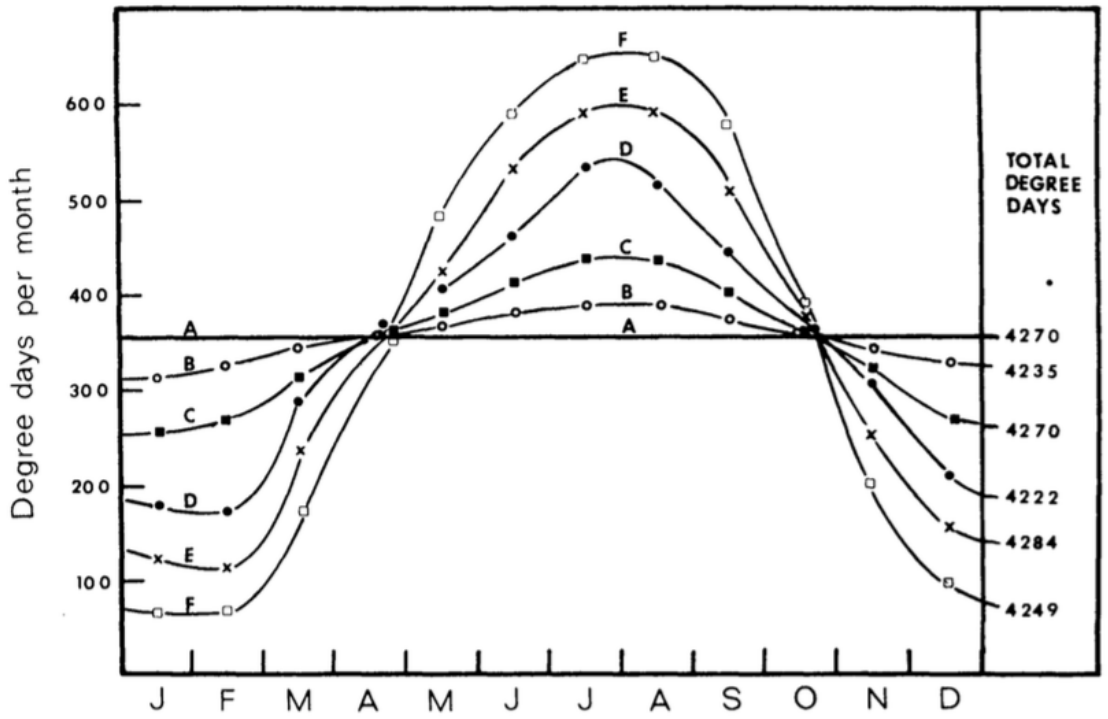


FIG. 1.—Isotherm lines of groundwater temperature for the continental United States (after Collins 1925).

Vannote and Sweeney 1980

Seasonal Regime Varies – Stream Type



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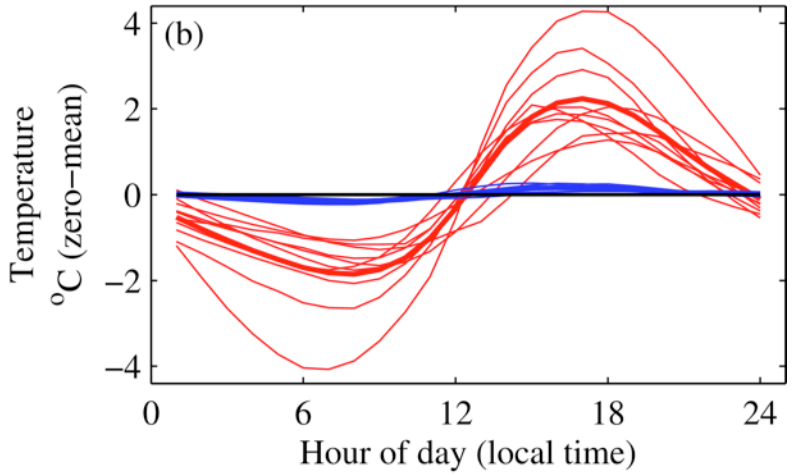
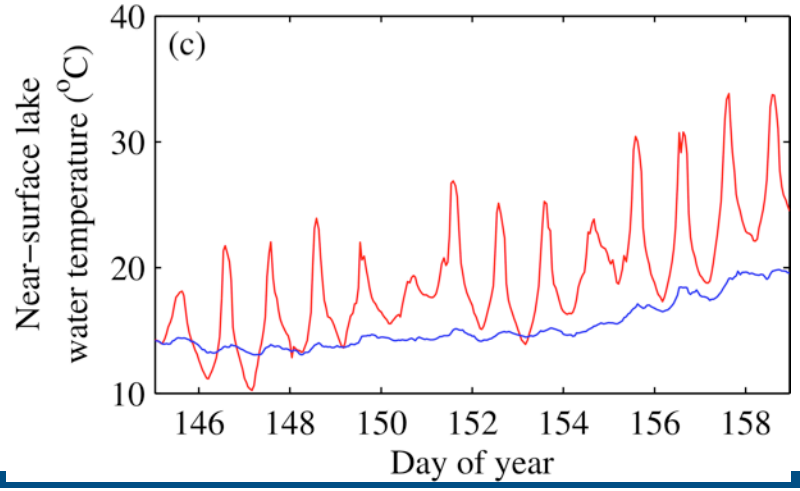
Vannote and Sweeney 1980

Water Temperature Varies – Lake Size





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Diel Regime Varies – Stream Size

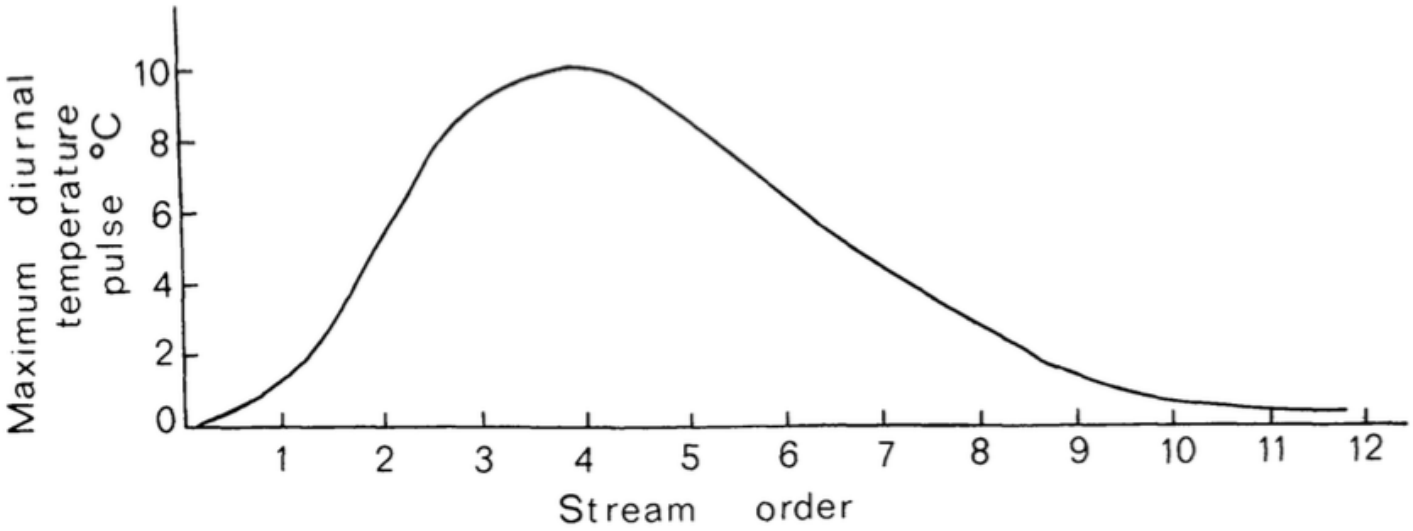

FIG. 3.—Maximum diurnal change in temperature as a function of stream order in temperate North America. Data are from unpublished White Clay Creek studies and water resource reports of the United States Geological Survey (U.S.G.S.).

Vannote and Sweeney 1980

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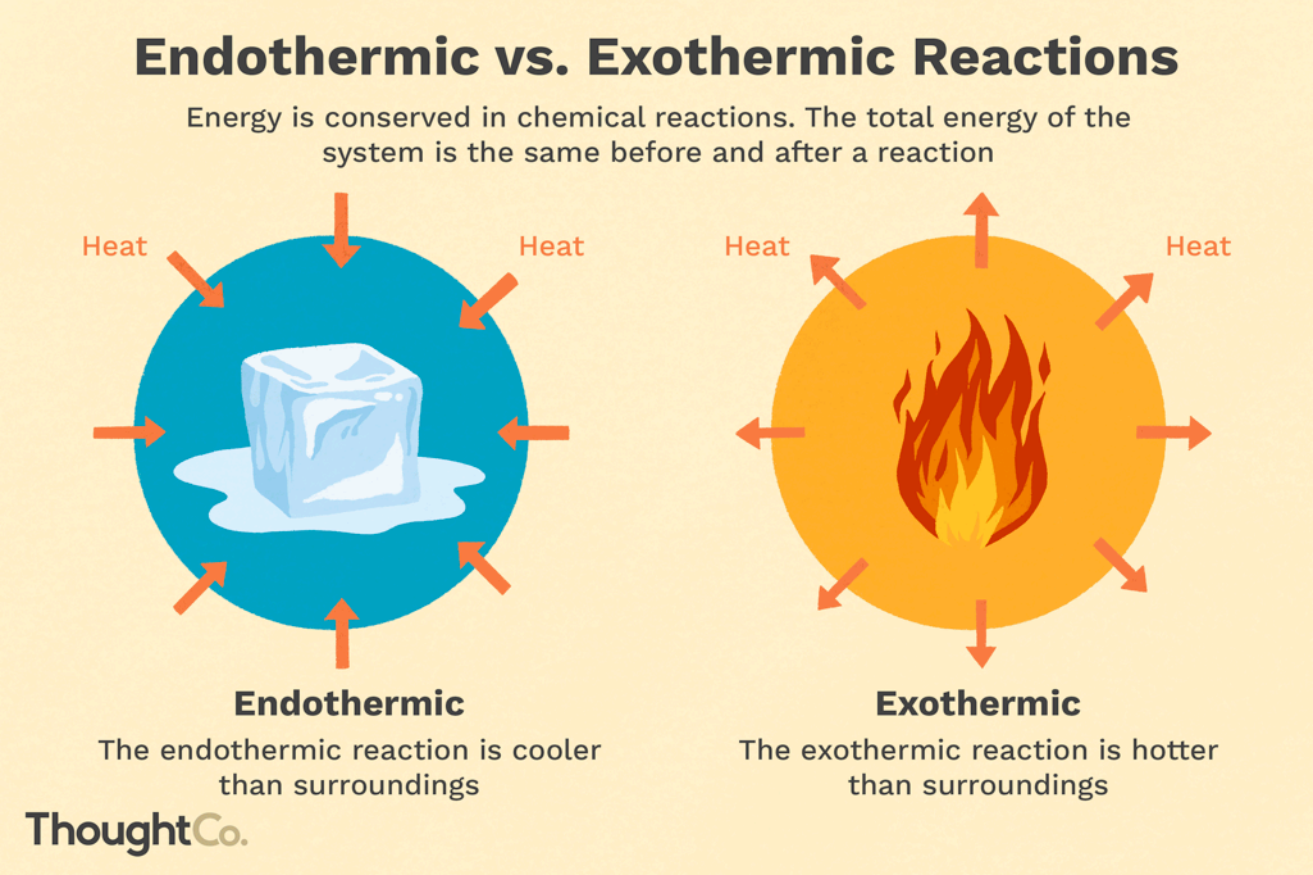
Chemical Reaction Rates Increase with Temperature



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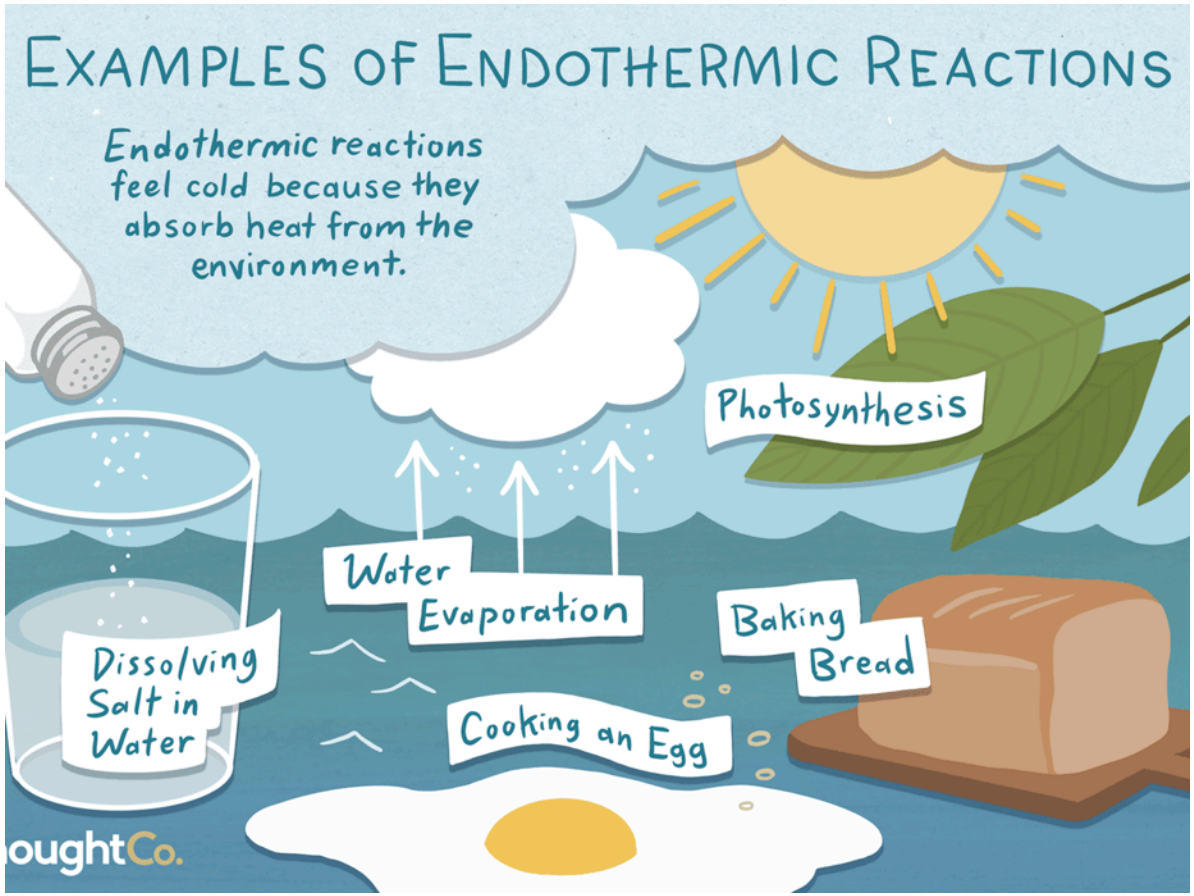

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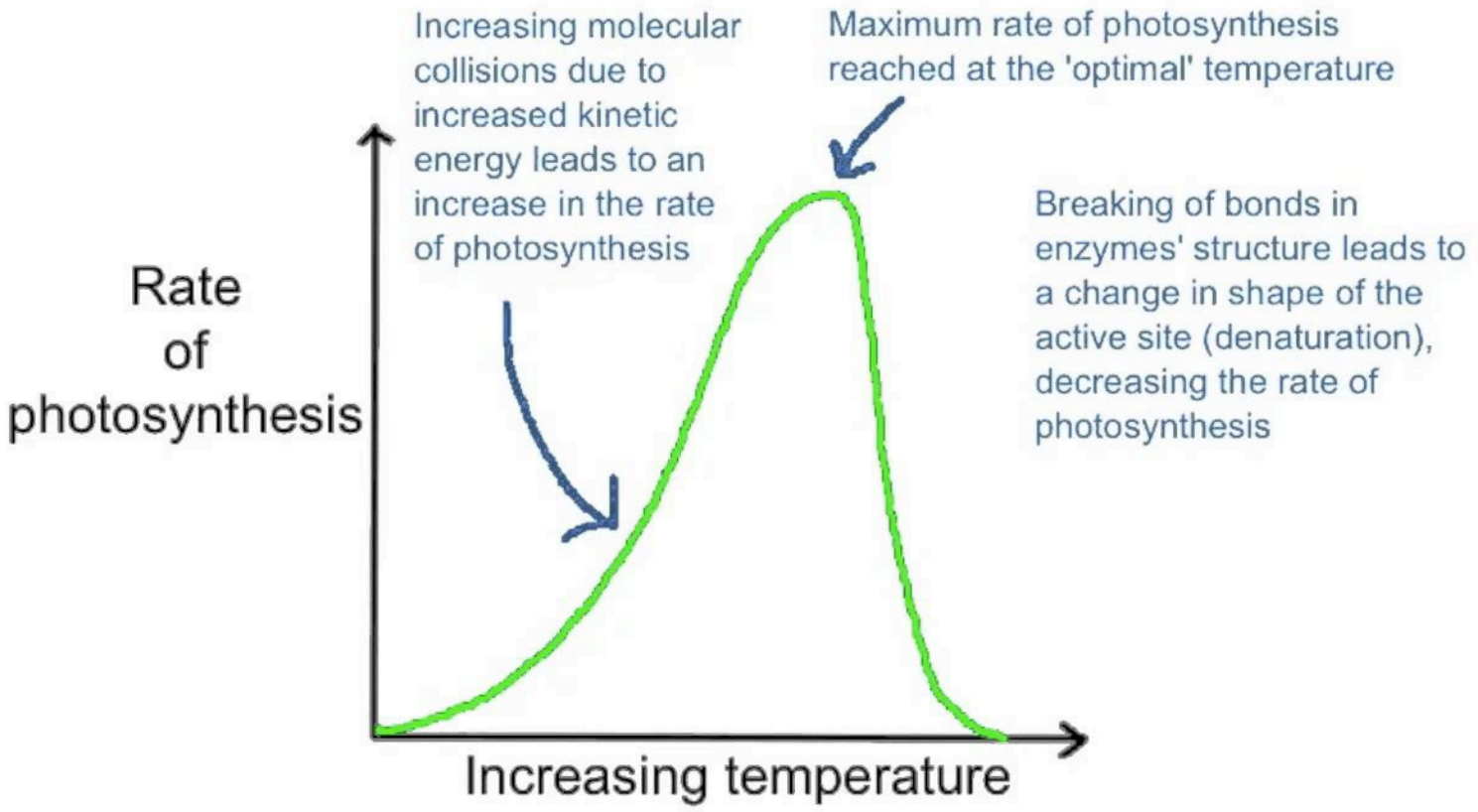
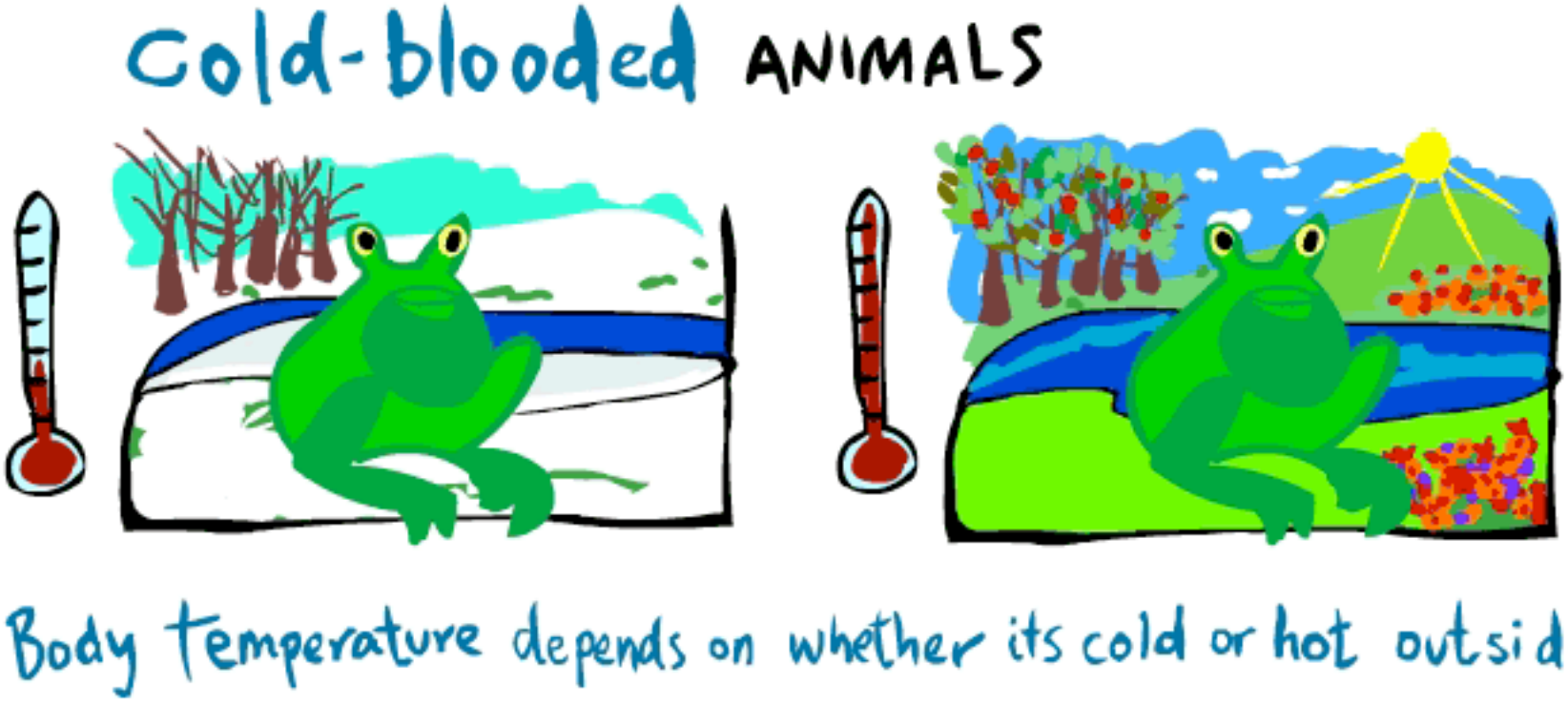


Aquatic Macroinvertebrates and Fish are Poikilotherms



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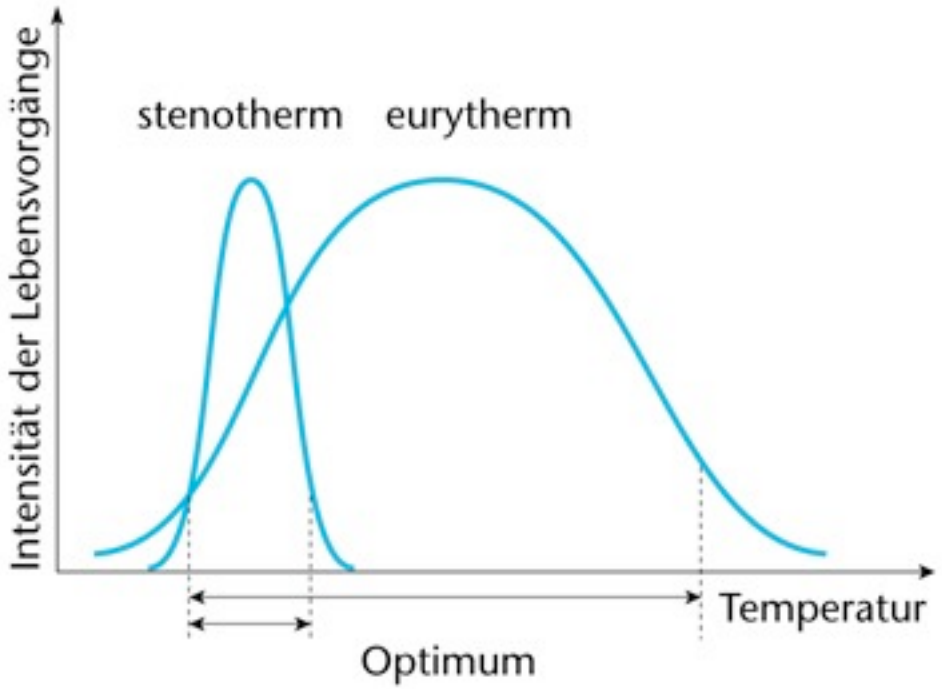

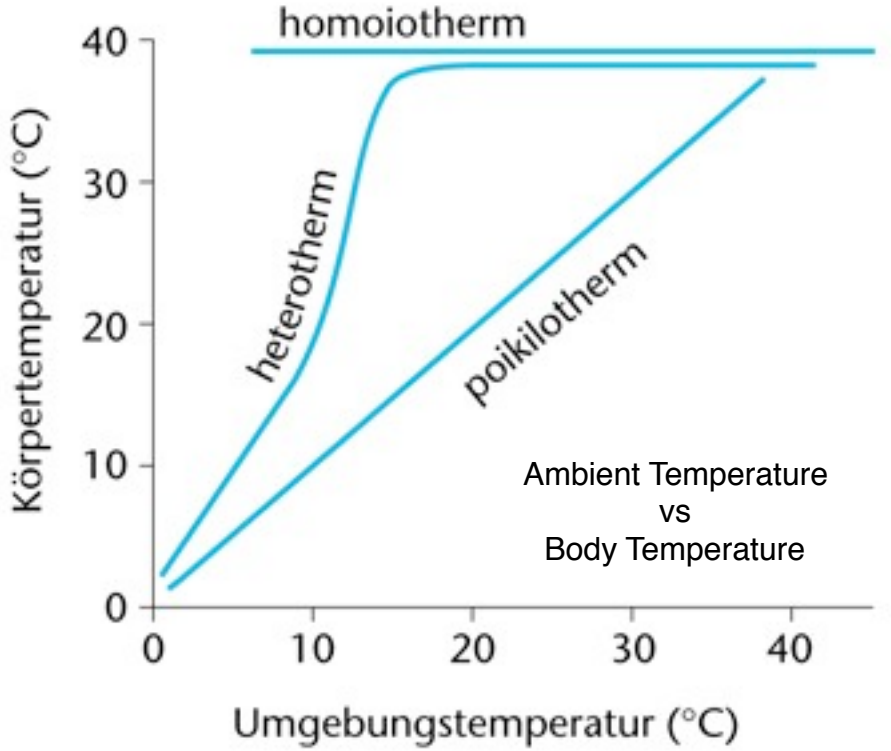

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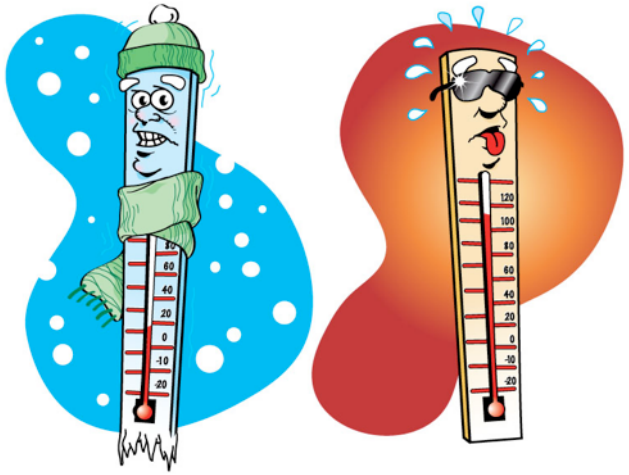
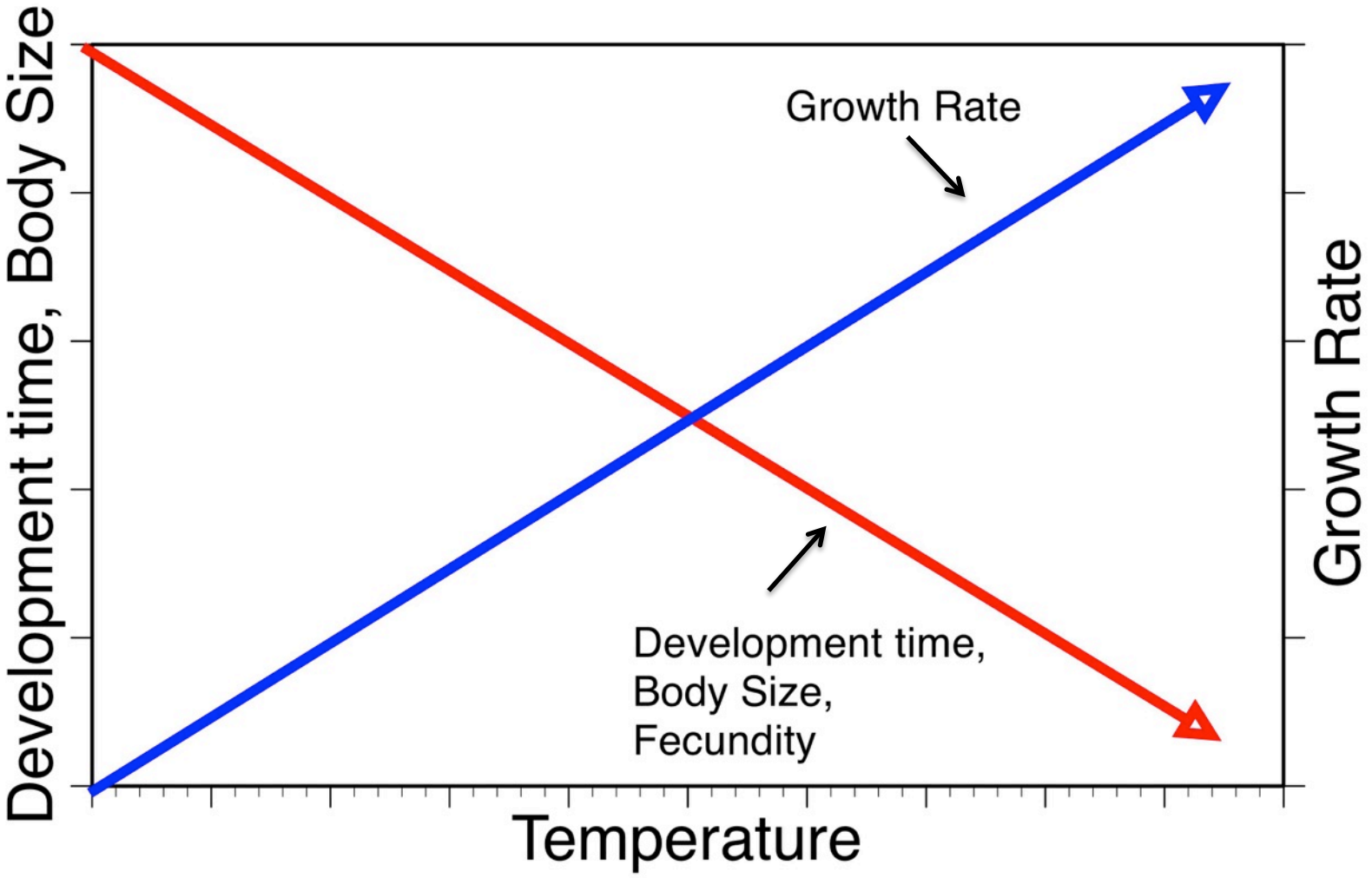
Temperature Affects Life Cycles

- Temperature known to be important for many stream organisms
- It has an effect on all macroinvertebrate **individuals** (and therefore **populations** and **communities)**
- Temperature affects individual
  - **Survival**
  - **Growth rate**
  - **Development time**
  - **Body size/fecundity**

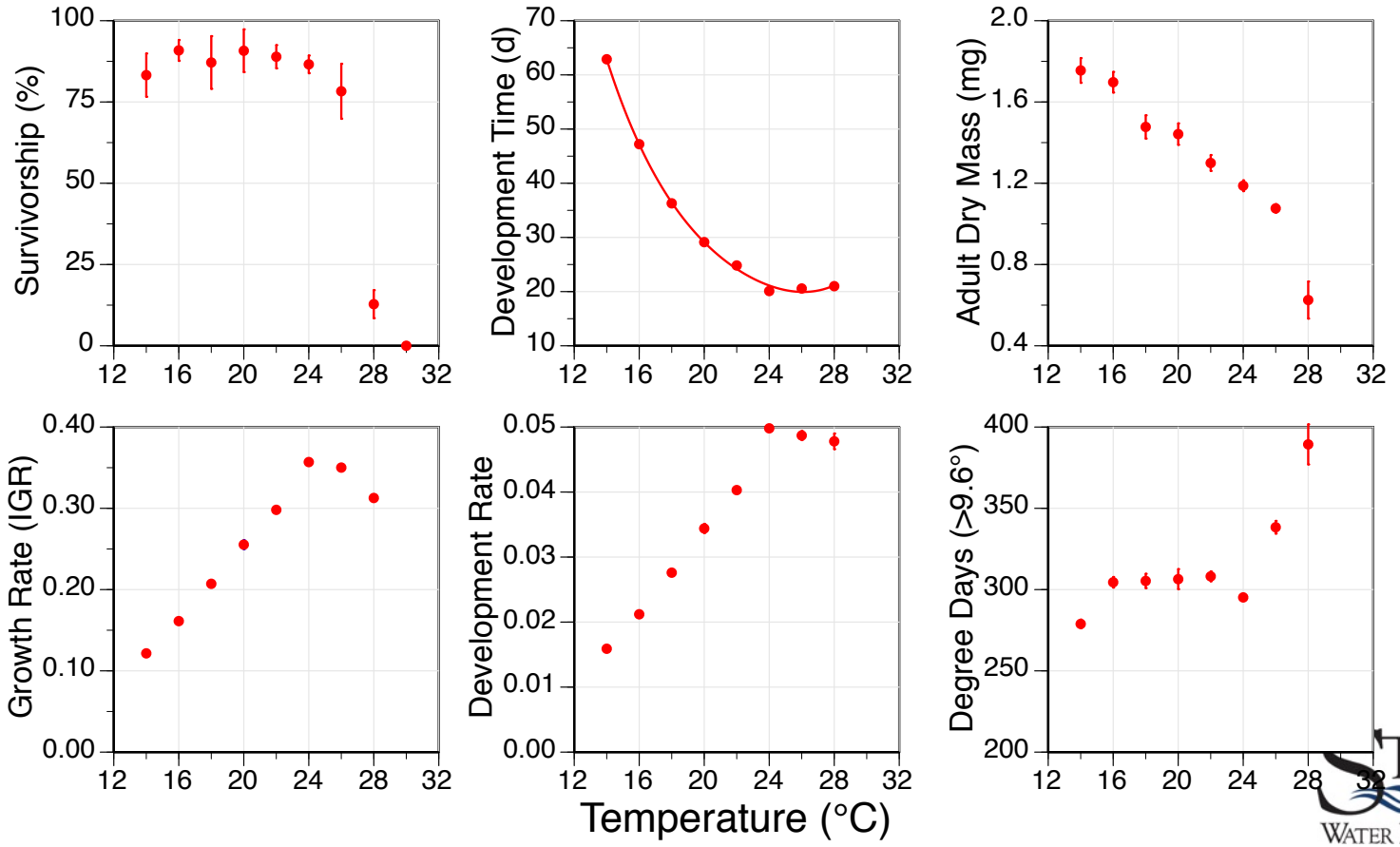


Response to temperature



Response to temperature

Neocloeon triangulifer
(Constant Temperature Experiments)



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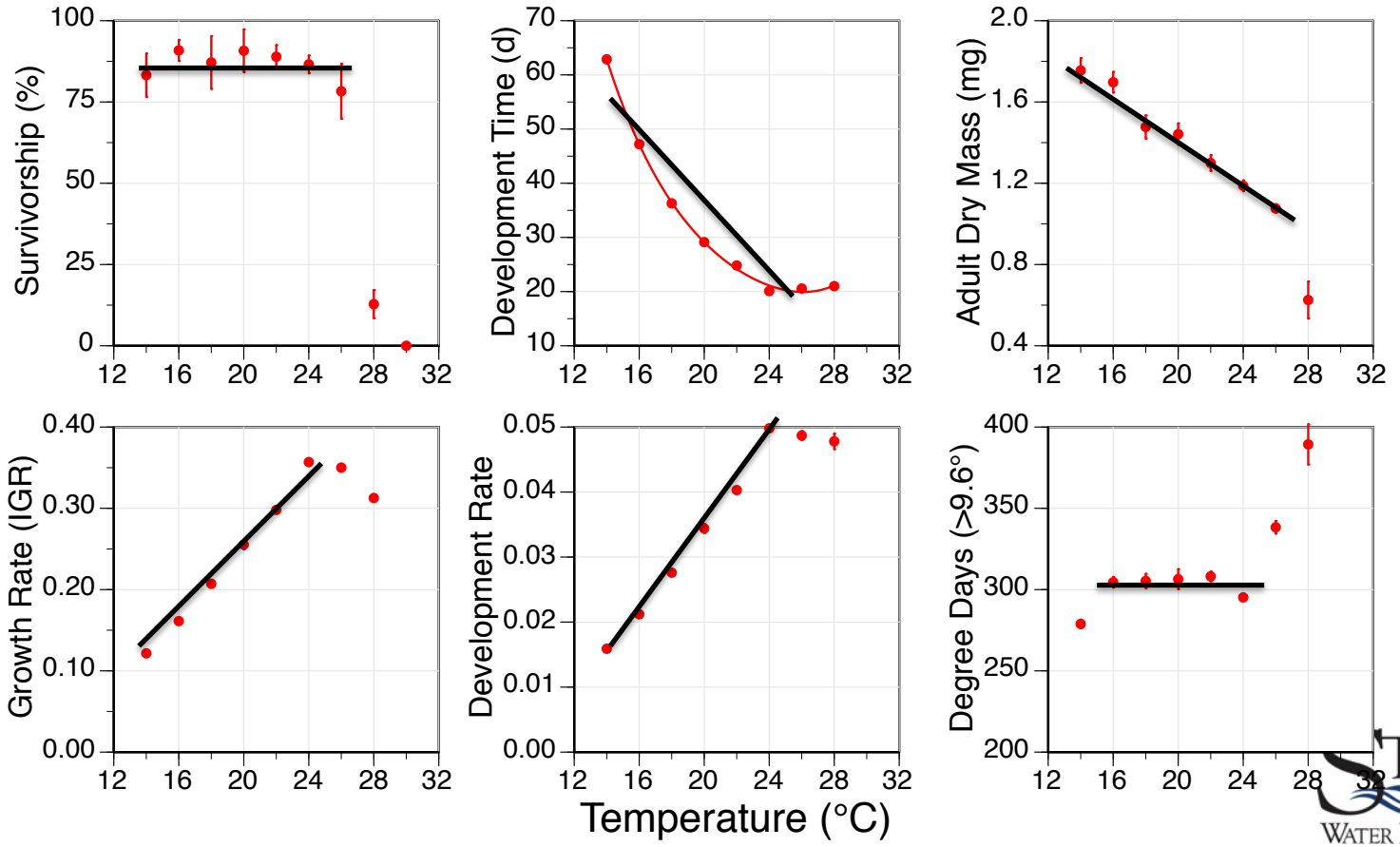

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Response to temperature

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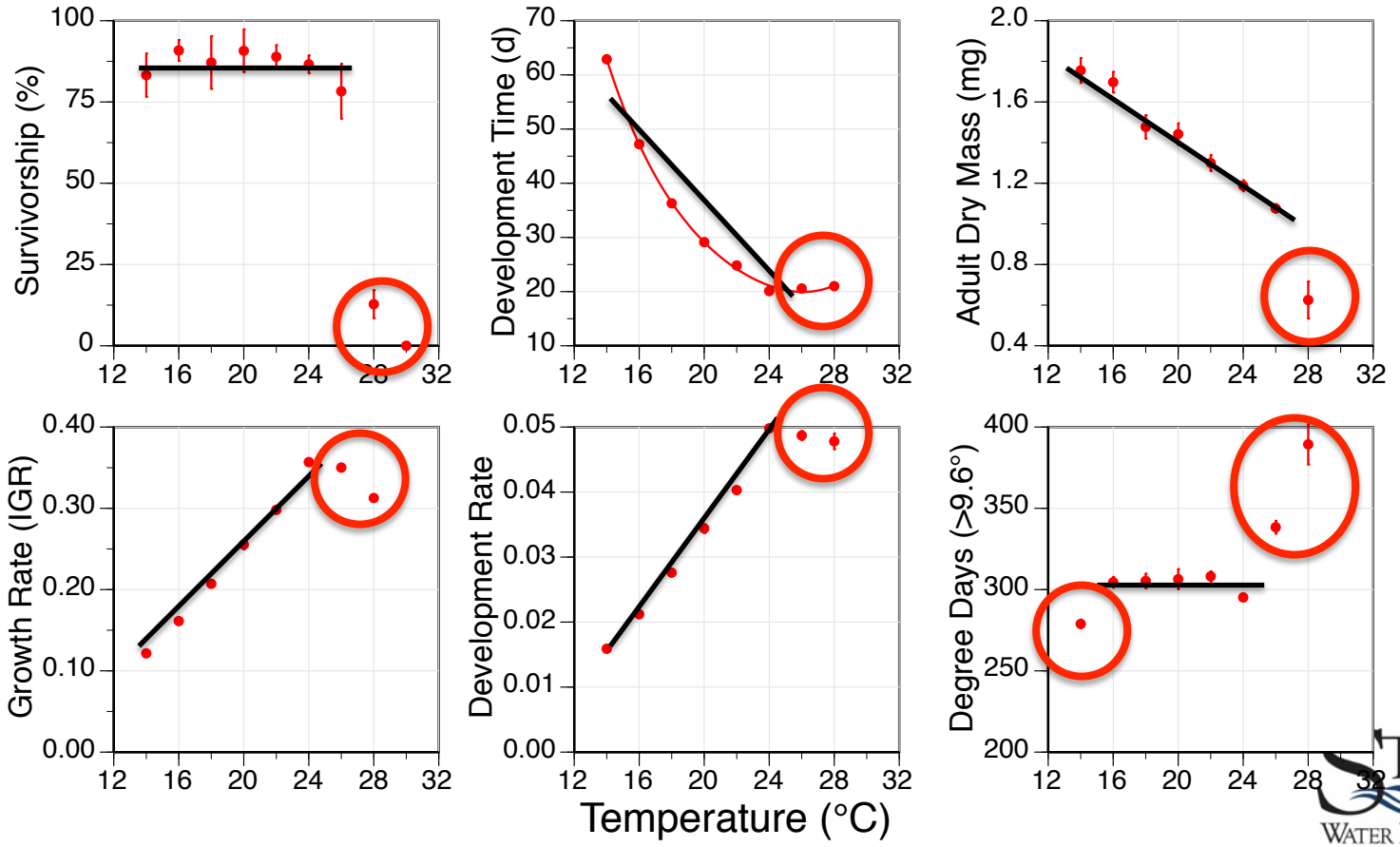
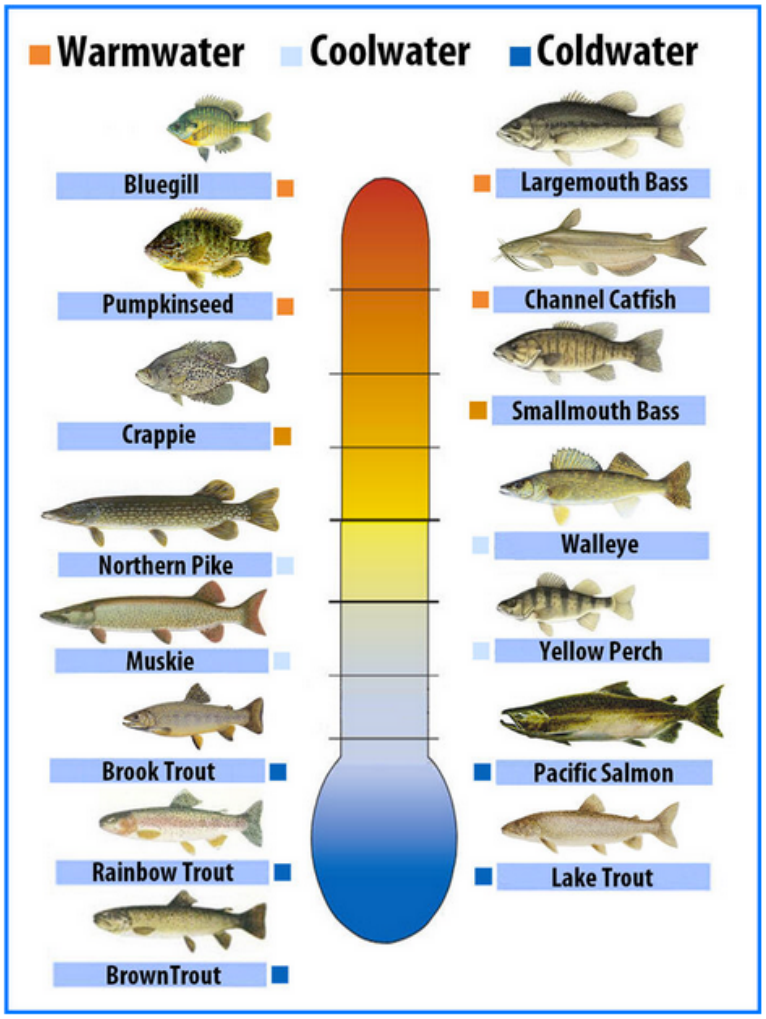


Temperature Defines Communities



Coldwater Fisheries
versus
Warmwater Fisheries

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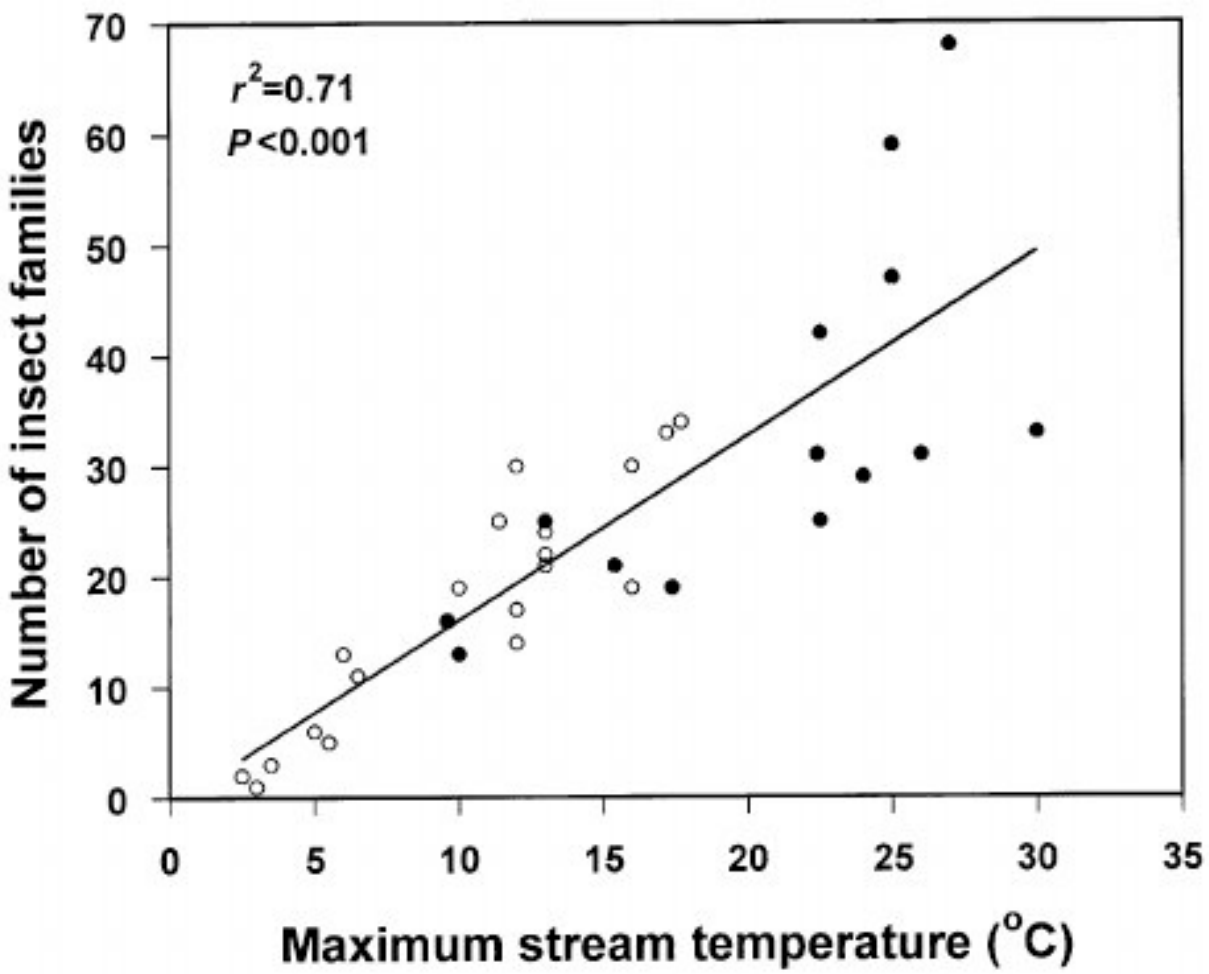
Temperature Defines Communities



Stream insect family richness increases with stream temperature for three regions in Ecuador and one in Denmark.

Jacobsen et al 1997

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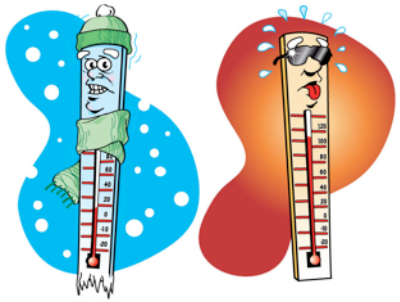
People affect Thermal Regimes

- Forests thinned, fragmented, or removed
- Running water turned to standing water – ponds and reservoirs
- Urban area become heat sinks
- Municipal and industrial effluents discharged to streams



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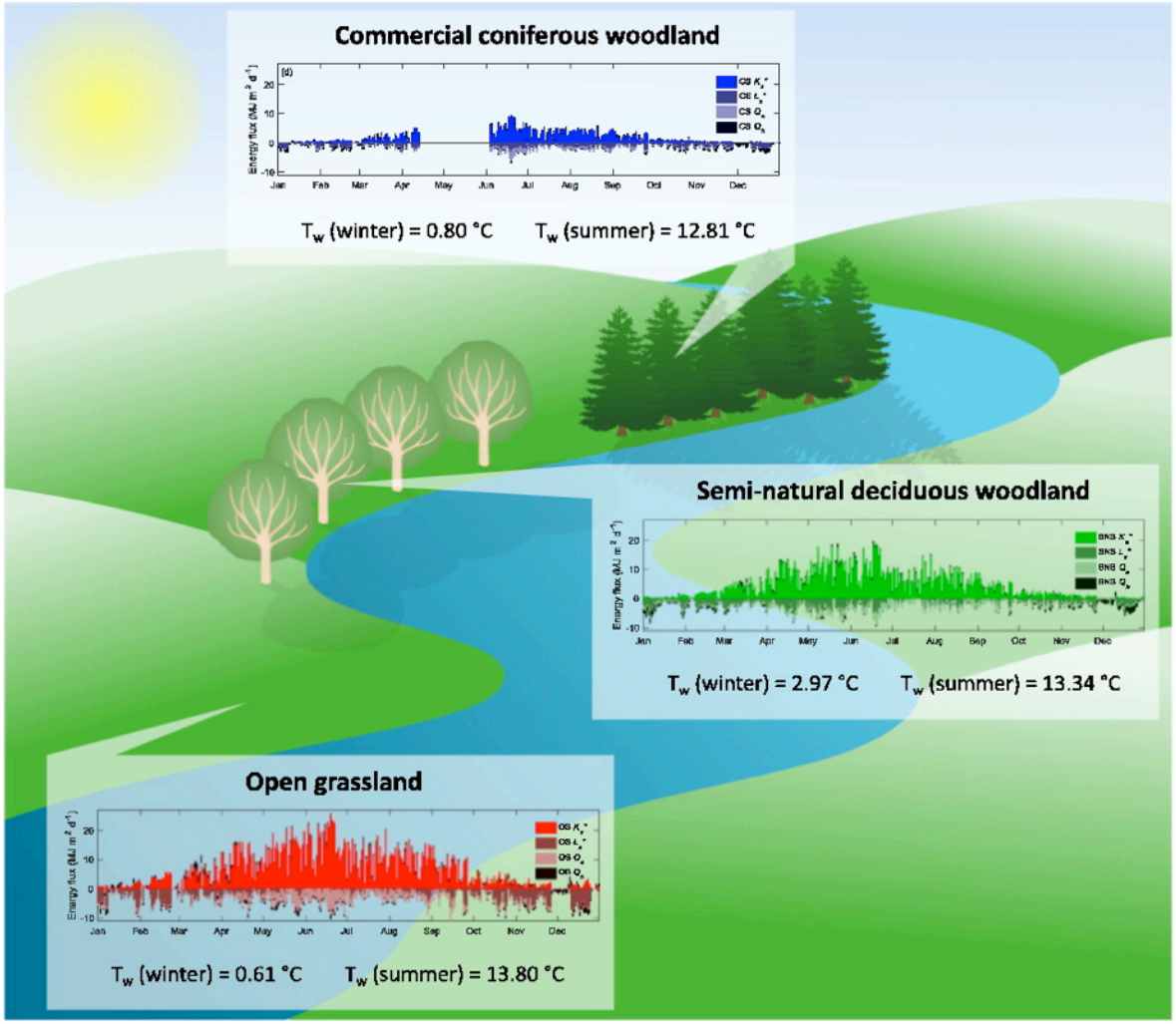
Deforestation affects a thermal regime



Cooler than normal in the winter

Warmer than normal in the summer

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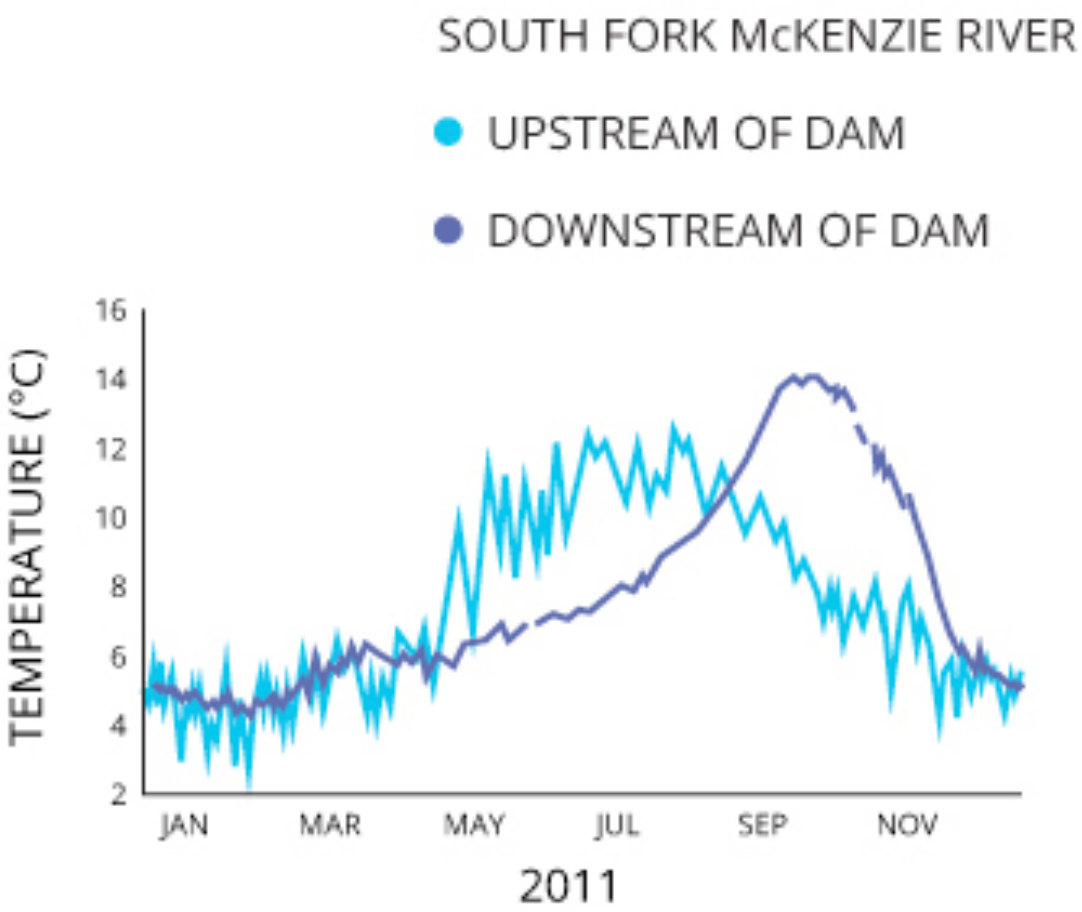
Dams affect a thermal regime



Cooler than normal at some times

Warmer than normal at some times

Depends on reservoir size and operation

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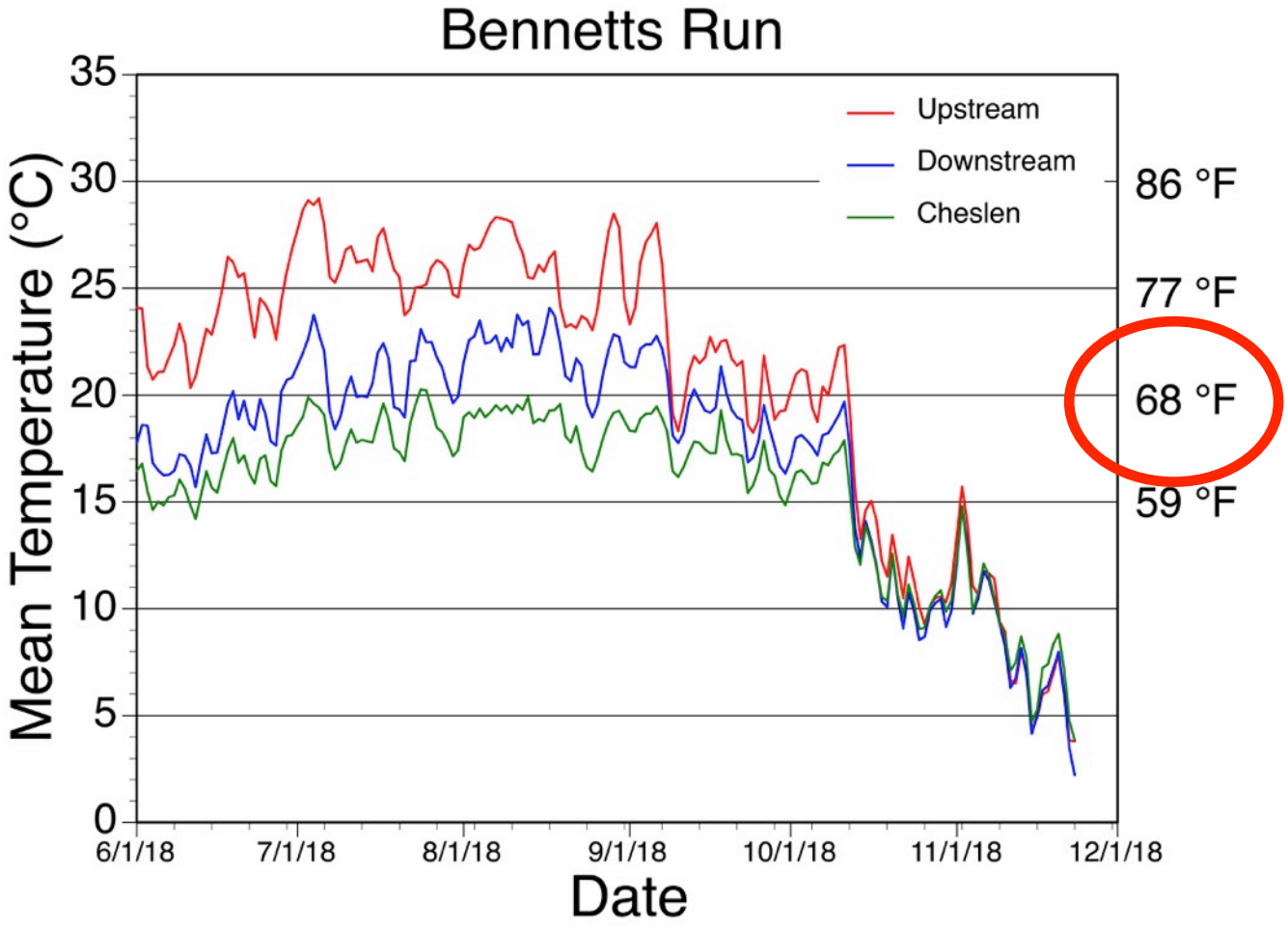
Ponds Increase Stream Temperature



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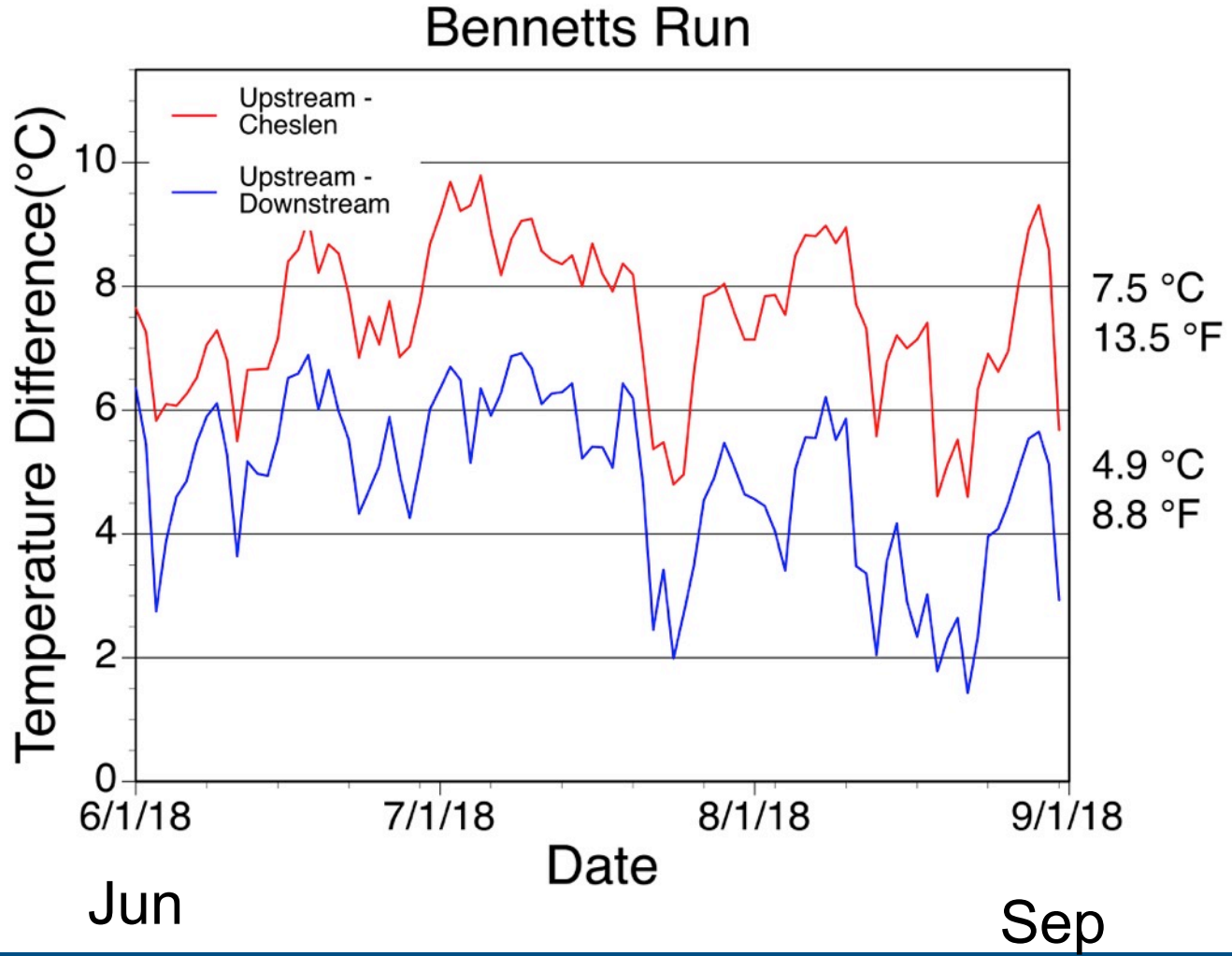

Difference =
+ 2.6 °C
+ 4.7 °F

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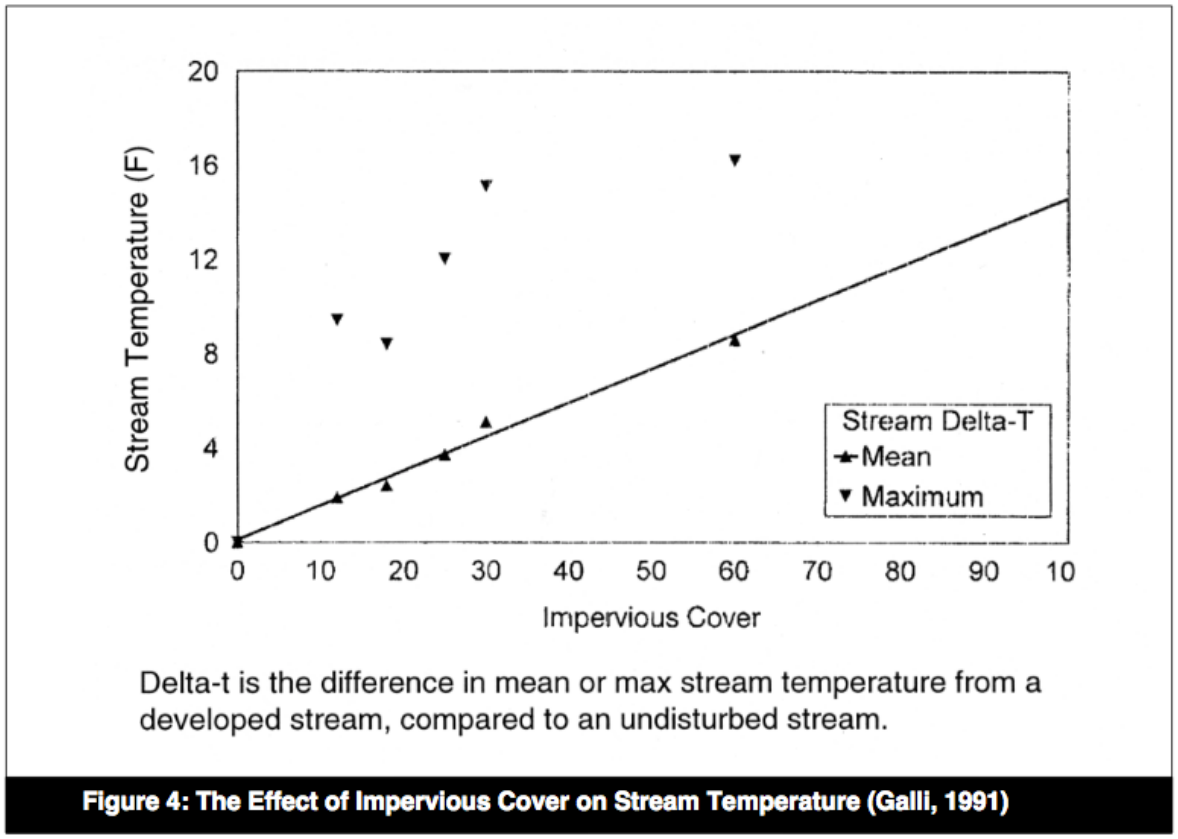
Urbanization Increases Stream Temperature



Delta-t is the difference in mean or max stream temperature from a developed stream, compared to an undisturbed stream.

Figure 4: The Effect of Impervious Cover on Stream Temperature (Galli, 1991)

Urban areas tend to be warmer (heat island)

Urban streams tend to be warmer than normal

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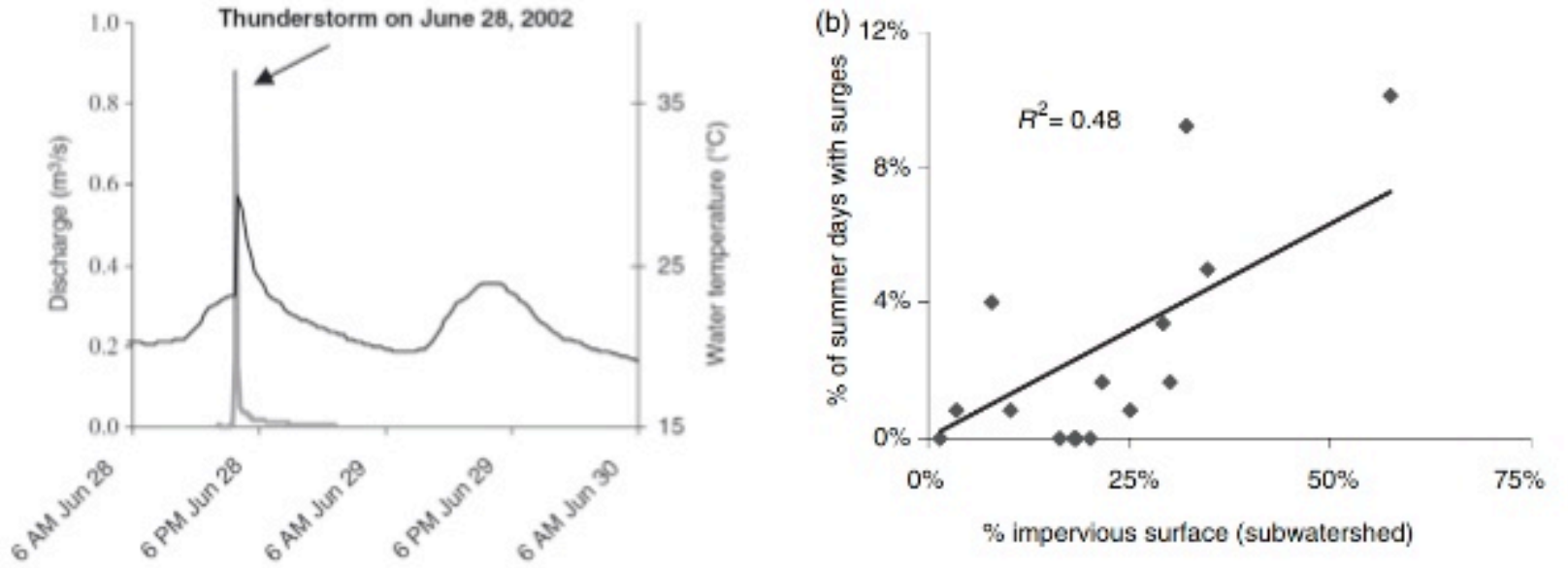
Summer storms bring in warm water as temperature surges



From Nelson & Palmer, 2007[10]

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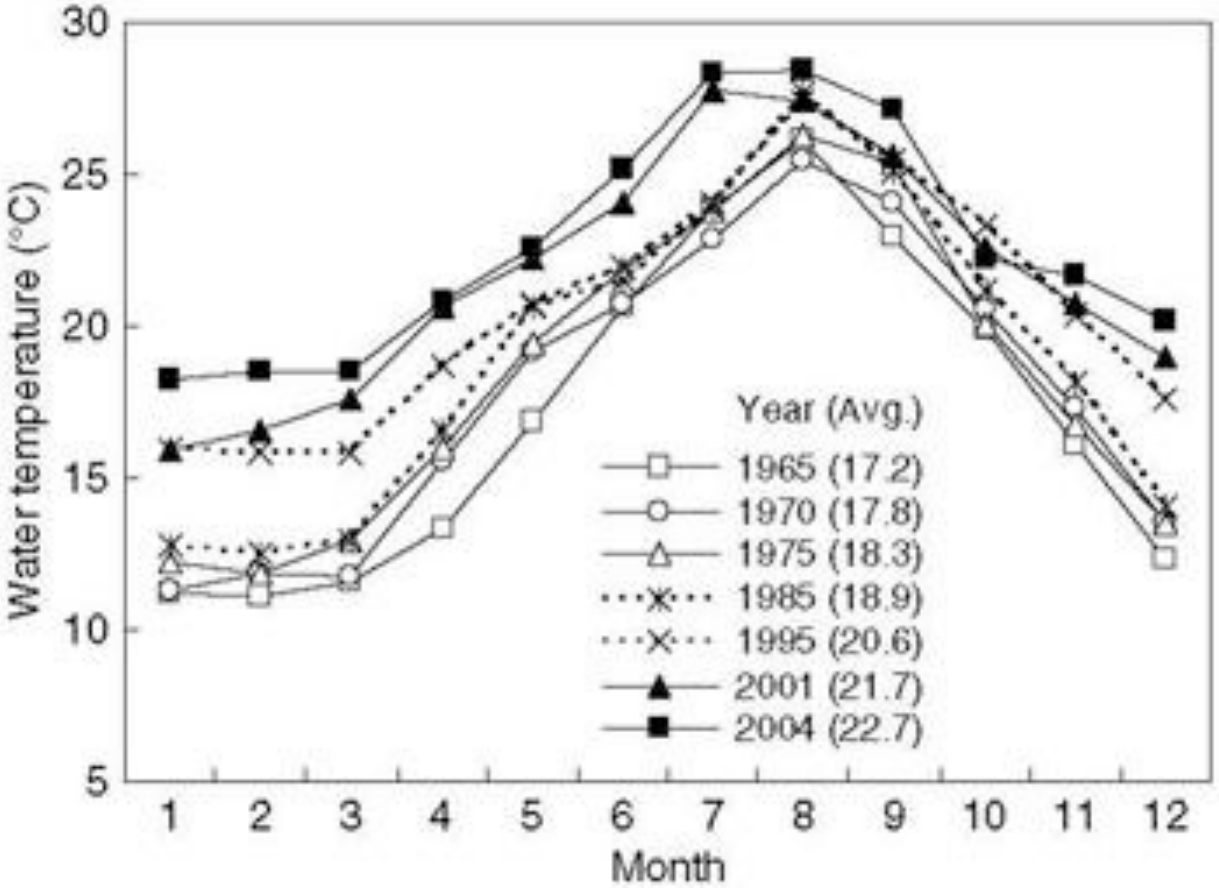
Urbanization Increases Stream Temperature



Wastewater can warm the stream throughout the year

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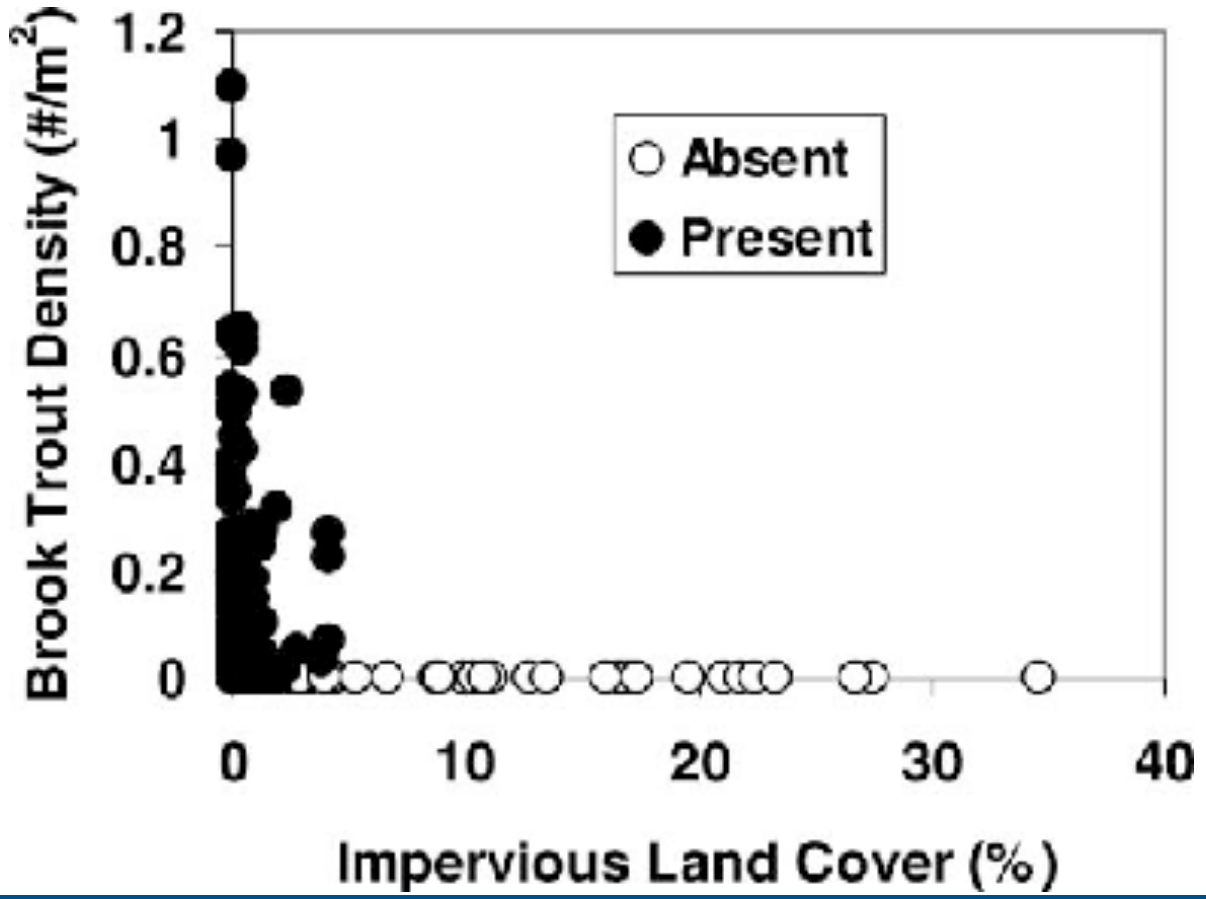
Urbanization Increases Stream Temperature



Brook trout – coldwater fish – decrease in abundance with urbanization

Brook Trout Declines with Land Cover and Temperature Changes in Maryland

July 2008 North American Journal of Fisheries Management 28(4):1223-1232

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Urbanization Increases Stream Temperature

- Is the waterway forested (shade) or open?
- Does the stream receive warm water from retention ponds?
- Wastewater discharges?
- Does the runoff flow off of hot surfaces?

Other issues increasing stream temperature:

Lower baseflow

Channel morphology – wider and shallower

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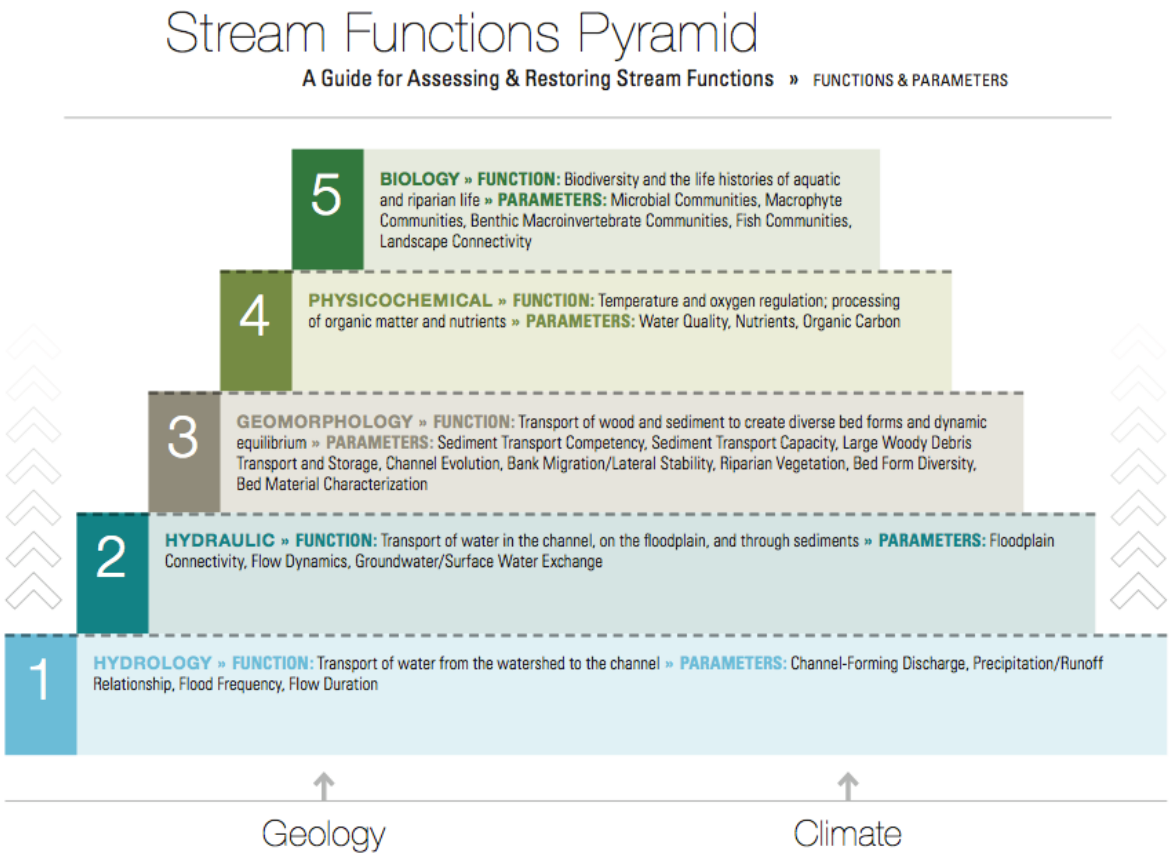
Stream Functions Pyramid – A Tool for Assessing and Restoring Stream Functions Functions & Parameters

Toxins?



Biology

Chemistry & Temperature

Geomorphology

Hydrology

Quantity & Timing

Points to Remember

- Temperature is important – really important
- Temperature varies naturally – diel, seasonal, annual – within a watershed, among watersheds
- Humans have already modified stream temperature, in addition to climate change

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Questions?


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