I was hoping you could summarize what we know about how changing temperature affects BMI communities in PNW rivers.

Specifically. I'm interested in

* What aspects of temperature (e.g., averages, threshold exceedances, maxima) have the most impact on BMI communities?
* What metrics (e.g., annual mean, annual max, annual max 7DADA, annual ATUs, mean or max or 7DADA/MWAT during critical periods) best predict these shifts?
* What community metrics (e.g., FFG composition, taxa richness, total abundance, taxa specific abundance, BIBI scores) best represent shifts that matter for anadromous salmonids?
* How do different changes in temperature correspond to changes in emergence timing versus overall community structure?
  + That is, do small changes result in changes in timing only? Or, can even small changes result in changes in community structure? Is there a tipping point above which changes in T result in changes in community structure, but below which the community remains intact but the taxa present emerge at different times?

At the end of your effort, I would expect to see:

1. A folder with as many PDF copies of the source articles as you can track down,
2. A reference management library export (e.g., from EndNote or Zotero) with QC'd entries for all the papers you find, and
3. A short memorandum structured around the three research questions above, that is well cited and would be written at a level that sections of it could be slotted into a client report.

You can bill this to 21-042 Task 6 (Detail Reasonable/Feasible Opts).

Deadline: NLT March 14th

Methods: Look through first 5 google scholar pages for each of the following key word searches

* For Q1: What aspects of temperature (e.g., averages, threshold exceedances, maxima) have the most impact on BMI communities?
  + Google scholar: Key words: Temperature AND ‘Benthic Macroinvertebrate’
* For Q2: What metrics (e.g., annual mean, annual max, annual max 7DADA, annual ATUs, mean or max or 7DADA/MWAT during critical periods) best predict these shifts?
  + Google scholar: Key words: ‘Temperature Metrics’ AND ‘Benthic Macroinvertebrate’
  + Key words: ‘Seven Day Average Temperature’ AND ‘Benthic Macroinvertebrate’
  + Key words: ‘Seven Day Temperature’ AND ‘Benthic Macroinvertebrate’
  + Key words: ‘Accumulated Thermal Units’ AND ‘Benthic Macroinvertebrate’
  + Key words: ‘Maximum Weekly Average Temperature’ AND ‘Benthic Macroinvertebrate’
  + Key words: ‘Maximum Average Temperature’ AND ‘Benthic Macroinvertebrate’
* For Q3: What community metrics (e.g., FFG composition, taxa richness, total abundance, taxa specific abundance, BIBI scores) best represent shifts that matter for anadromous salmonids?
  + Google scholar: Key words: ‘Benthic Macroinvertebrate’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
  + Google scholar: Key words: ‘Benthic Macroinvertebrate Community’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
  + Google scholar: Key words: ‘Benthic Macroinvertebrate Community Shift’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
  + Google scholar: Key words: ‘Benthic Macroinvertebrate Functional Feeding Group’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
  + Google scholar: Key words: ‘Benthic Macroinvertebrate Taxa Richness’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
  + Google scholar: Key words: ‘Benthic Macroinvertebrate Total Abundance’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
  + Google scholar: Key words: ‘Benthic Macroinvertebrate Taxa Abundance’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
  + Google scholar: Key words: ‘Benthic Macroinvertebrate Index of Biotic Integrity’ AND (Salmon OR Trout OR Steelhead OR Char OR Salmonid)
* For Q4: How do different changes in temperature correspond to changes in emergence timing versus overall community structure?
  + Google scholar: Key words: Temperature AND `Benthic Macroinvertebrate Emergence Timing’
  + Google scholar: Key words: Temperature AND `Benthic Macroinvertebrate Community’
* For PNW context
  + Google scholar: Key words: Temperature AND `Benthic Invertebrate` AND `Pacific Northwest`
  + Google scholar: Key words: `Temperature AND `Freshwater` AND `Benthic` AND `Invertebrate` AND `Pacific Northwest`
* Literature was then restricted to which digital copies were freely/publicly available
* Generating the following list of references

Kehmeier. 2024. Blue River Temperatures Analysis

* Maximum 30 day average temperature (M30AT) has greatest relevance for fish growth and recruitment (Roberts et al. 2013). It represents the average temperature observed during the hottest month.
  + Roberts, J. J., K. D. Fausch, D. P. Peterson, and M. B. Hooten. 2013. Fragmentation and thermal risks from climate change interact to affect persistence of native trout in the Colorado River basin. Global Change Biology 19:1383-1398

Mustonen. 2018

* Only identified chironomids and omitted them from statistical analysis
* Mean Annual Air Temperature MAAT (MAAT) was most important predictor of species distributions
* MAAT was negatively associated with latitude
* BMI **community assemblag**e changed the most for streams with the coldest current (1981-2010) Mean Average Air Temperature (MAAT). Assessed with Bray Curtis. Sites with air MAAT less than 2 C and over -3 C had the greatest changes in community assemblage. Initially warmer sites had less change in community composition
  + Future scenarios were considered as 2070-2099.
* **Richness** changed the least for sites with an initial MAAT of approximately 0 Celsius
* **Richness** changed the greatest for sites with an initial MAAT below -2 Celsius
* Predicted larger changes in headwaters than big rivers (headwaters are more flow sensitive)
* Expected taxa richness changed least for streams with Current MAAT of approximately 0 C. Coldest sites experienced greatest changes in the direction of increasing number of taxa (richness).
  + Cold adapted species moved north and replaced by species more tolerant of warm conditions (Daufresne et al. 2007; Durance and Omerond 2007)
  + South central sites remained stable or decreased in richness

Durance and Omerond 2007

* Warming stream temperatures moderately changed species assemblage and decreased spring (April) BMI abundances, but only in circumneutral streams where BMI species diversity and BMI abundance were the highest
  + Reductions in April abundance is suspected to be a result of changes in emergence timing (associated with increased growth rates; Elliott et al. 1988) or energy flows (increased predation from fish; Kishi et al. 2005, reduced leaf litter decomposition; Lepori et al. 2005)
* Acidification overrides climate as it reduces species richness and abundances (Bradley & Ormerod, 2002a; Kowalik & Ormerod, 2006)
* (Mouthon & Daufresne, 2006) also observed reduced BMI richness with increasing temp
  + This is in contrast to the arctic and glacial studies….
    - Mouthon J, Daufresne M (2006) Effects of the 2003 heatwave and climatic warming on mollusc communities of the Saone: a large lowland river and of its two main tributaries (France). This citation however is for Mollusca in a river atypical of habitat conducive to salmonids…
* (Ormerod & Tyler, 1991) found reduced BMI abundance reduces energy transfers to predatory birds at important reproductive periods
* Lento et al. 2020:
  + southeastern New Brunswick
  + Pteronarcyidae, Perlidae, and Perlodidae were more common at sites with a greater number of degree days above 19 Celsius. Leuctridae, Nemouridae, and Chloroperlidae were stoneflies associated with cooler sites
* Weber et al. 2014
  + Studied temperature, benthic/drift invertebrates, and O. Mykiss in John Day River tributaries
  + O. Mykiss consumption rates of invertebrates in drift was lower at higher population densities
  + Drift biomass density (a metric of food abundance) decreased as population density increased but density explained just 26% of the variation in drift biomass (R squared = .26)
  + Density explained just 4.7% of the variation in fish growth
  + Food ability here is limiting
  + Temperature and food ability both contribute to Salmonid growth
    - Ignoring food ability and focusing only on temperature may lead to biased estimates of growth potential
* Fierro et al. 2019
  + Not super useful
  + Chilean study
  + Temperature influences benthic macroinvertebrate assemblages in streams
* Pretty et al. 2021
  + Not super useful
  + Temperature influences benthic macroinvertebrate assemblages in lakes
* Daufresne et al. 2003
  + Upper rhone river
    - Used fish data (1979–1999) and invertebrate data (1980–1999)
    - Temperature warmed by 1.5 C on upper Rhone between 1979 and 1999
    - Thermophilic fish and macroinvertebrates replace thermophobic fish and macroinvertebrates
    - Significantly correlated with water temperature
* Brush 2016
  + Not Super useful in and of itself…. May remove from reference/citations
* Hinz and Wiley 1998
  + 17 small, coldwater michigan trout streams
    - Looked at temperatures, macroinvertebrate populations, and brook and brown trout growth rates
  + Mean Summer temp ranged between 8.7 and 14.4 C among the 17 sites, so these are very cold temperature streams that really don’t reach stressful temperatures for trout. Therefore, since temperatures are below the optima, higher temperatures increase growth rates
  + Chironimids and Baetids were most common
  + Predator macroinverts were mostly comprised of *Rhyacophila* and *Isogenoides*
  + *Direct quotes*
    - *“Annual maximum temperature (r=0.564),*

*mean annual daily temperature fluctuation (r=0.390), and all the summer and July temperature summary parameters were significantly and positively correlated with total macroinvertebrate biomass per unit area (Table 6). Grazer biomass was significantly correlated with summer temperature fluctuation (r=0.391) and July temperature fluctuation (r=0.371), but none of the other temperature summary parameters. Filter-feeders were significantly and positively correlated with all of the summer and July temperature summaries and the annual maximum and temperature fluctuations. Biomass of total macroinvertebrate predators was not significantly correlated with any of the temperature summary statistics except for summer temperature fluctuation (r=0.378).”*

* + - *“Grazer, filter-feeder and total density of non-predaceous macroinvertebrates were all positively correlated with temperature summaries such as maximum and mean daily summer temperature.”*
  + Temperature was positively correlated with macroinvertebrate biomass densities
    - Grazers densities were positively correlated with mean daily summer stream temperature fluctuations
    - Filter feeder densities were correlated with summer and July temperature thermals, annual maximum temp, and daily thermal fluctuation
    - Juvenile brook trout was highly positively correlated with daily temp fluctuation
    - Juvenile brook trout density was very Negatively correlated with mean daily temperature during July
    - The maximum daily temperature in July was highly positively correlated with juvenile brook trout production.
  + Seems to indicate some fairly species specific dependencies here in terms of correlations between different prey taxa biomass, different metrics of energy transfer, and trout biomass…
  + Mean July thermal fluctuation was most correlated with brook trout growth (r=0.801)
    - Mean Temp flux is mean(daily maximum-daily minimum)
  + Using a causal path model
  + found that temperature most affected juvenile brook trout growth rates
  + Half of the temperature effect were indirect effects of temperature on growth through temperature impacts to ration
    - Ration also had a statistically significant effect on brook trout growth rates
      * Predator BMIs were slightly more important than grazers
      * Biomass of predators and grazers increased with increasing temperature
        + This was the mechanisms for the indirect temperature affect on growth rates
  + Multiple linear regression of growth rate with July flux, the trophic ratio, And a different lm of growth rate vs July flux, non predatory BMI biomass, and predatory BMI biomass explained 71 and 73 % of the variation in growth respectively
  + Key take away here is that temp exerts direct influences on growth, but also indirect through influencing prey (BMI biomass).

Wang and Kanehl (2003) USE IN DISCUSSION OF FUNCTIONAL GROUPS

* + Study of Wisconsin and Minnesota coldwater streams
  + Used multiple temperature metrics including
    - Maximum daily mean, instantaneous minimum/maximum of temp, max/minimum of first 3 weeks of July, max/min of 7 day mean temperature
    - Ultimately Maximum of the 7 day mean temperature and minimum of first three weeks of July temperature were kept by the forward selection methodology in the Canonical Correspondence Analysis (CCA)
  + As temp increased, % EPT taxa, filterers, and gatherers went down
  + Stream temps decided taxa richness
  + Relative Abundance of functional feeding groups was positively correlated with taxa richness and % predators and negatively correlated with the % of gatherers and % of the two most common taxa.
  + Lots of other good background info sources on effects of temperature on BMIs in this one

USE IN DISCUSSION OF IMPACTS TO SIZE AND EMERGENCE TIMING

* Vannote, R. L. and B. W. Sweeney, 1980. Geographic Analysis of Thermal Equilibria: A Conceptual Model for Evaluating the Effect of Natural and Modified Thermal Regimes on Aquatic Insect Communities. The American Naturalist 115:667-695.
  + Temperature impacts insect growth, metabolism, fecundity, and generation time, and size at emergence
  + Movement in conditions away from the thermal optimum leads to changes in these characteristics
  + Lagging larvae (eggs laid latest) reach the smallest size as larvae and emerge as towards the end of emergence as the (on average) smallest adults
    - Respiration/g decreases as body size increases but increases as temperature increases
    - For small individuals their respiration/g increases more relative to their body size, so they are less energetically efficient as the water warms
    - Thermal shifts influence energy use
    - Adult body size and fecundity decrease with temperature within a cohort
      * Warmer winters water temps would be associated with earlier emergence, reduced adult body size, and reduced fecundity
        + This is what they observed in experiments
        + Adult emergence was synchronous
      * Higher temperatures
        + Initiate emergence in a fairly size independent manner
        + Reduce larvae growth potential
        + Accelerate rate of adult tissue development
    - Consistent with the above, for species with many generations the year, summer and winter emerging cohorts should be very different in size
      * This is what they have observed (cohorts in summer tend to be smaller with lower fecundity)
* Vannote et al. 1980
  + Rivers tend to have BMI communities that can be divided into functional feeding groups (grazer, shredder, filter feeder)
    - * Within these groups, temperature synchronizes the timing of taxa populations and reduces competition by separating rearing and emergence timings of species temporarily.
* Quinn, J. M. and C. W. Hickey, 1990. Characterization and Classification of Benthic Invertebrate Communities in 88 New Zealand Rivers in Relation to Environmental Factors. New Zealand Journal of Marine and Freshwater Research 24:387-409.
  + Used mean annual daytime temperature (MANT)
  + And MAX Temp = MANT + half mean winter—summer range (°C)
  + Thermal regimes impact BMI communities
  + Used non-parametric ANOVAs
    - Plecoptera particularly restricted to cooler streams (<13 C mean annual daytime temp), and to a lesser extent Ephemeroptera (MaxTemp < 21.5)
* Lawrence et al. 2010
  + Shift in communities from those typical of cool wet years to those typical of warm dry years
  + Reduction in body size associated with decreases in precipitation and increases in temperature
  + North Coast B-BI was not affected by changes in temperature extremes or precipitation extremes
  + Ratio of expected to observed taxa, % EPT, and richness were also not impacted by variation in temperature and precipitation
  + They developed a locally based climate change indicator from the presence or absence of 9 BMI taxa (identified to genus)
    - Detected differences among sites associated with changes in precipitation and temperature
    - Also detected differences among 40 other sites in the San Francisco bay watershed.
  + General indices of BMI may not be sensitive to climate change impacts, and local specific indices based on local species compositions may need to be developed
* Castella et al. 2001
  + Examined European glacial fed streams from svalbard to Pyrenees
    - Many glacier fed streams
  + Used maximum temperature as a measure
    - Max temp in each reach over the entire study period explained 79% of variation in taxonomic richness
  + Found increasing max temp was associated with increasing richness
    - However, their study sites all had max temperatures below 16 Celsius
    - Taxa richness was greater at lower latitudes
  + Many (though not all, possibly due to not reaching upper limits of temperature thresholds for those taxa) densities were relatively hump shaped, reflecting preference for a thermal optima
  + There was a shift in taxa density and presence in some taxa
  + **So in very cold glacial streams (those below thermal optima for salmonids), warmer temperatures are likely to increase BMI richness**
  + Relatively few (under 7) taxa types were found near the glacial sources

Currie, D. J., Mittelbach, G. G., Cornell, H. V., Field, R., Guegan, J.F., Hawkins, B. A., Kaufman, D. M., Kerr, J. T., Oberdorff, T., O'Brien, E., & Turner, J. R. G. (2004). Predictions and tests of climate-based hypotheses of broad-scale variation in taxonomic richness. Ecology Letters, 7, 1121–1134.

* Physiological tolerance hypothesis
  + More physiological traits can live in warm/wet conditions than cold/dry
* Houghton et al. 2002
  + Functional feeding group is very dependent on riparian landscapes
* Fierro et al. 2015 USE FOR DISUCSSION OF FFGs
  + Biomass and richness of BMIs varies temporally
  + Dominant functional feeding groups also changed seasonally
    - Collector gatherers were more common in summer, all, and spring. In winter shredders and collector-gatherers were approximately equally dominant.

Hawkins, C.P. & J.R. Sedell. 1981. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology, 62: 387-397.

* The river continuum concept predicts a series of consistent longitudinal changes in stream macroinvertebrate communities due to changes in a variety of physical and biological factors, including temperature.
  + Stream morphology, water velocity, substrate, temperature, allochthonous and autochthonous energy inputs, and their interactions
* Seasonal shifts in functional feeding groups were observed
  + Shredders increased in autumn
    - This is perhaps more leaf input related than temperature related?
    - For shredders and scrapers, their abundance was related to measures of their primary food sources (CPOM and algae/periphyton respectively)

Resh et al. 2012

* Honestly they talked a lot about fish here. More useful in terms of its background references

USE IN DISCUSSION OF IMPACTS ON SIZE

Daufresne, M., K. Lengfellner & U. Sommer, 2009. Global warming benefits the small in aquatic ecosystems. Proceedings of the National Academy of Sciences 106: 12788–12793.

* Meta analysis showed an increase in smaller species, younger age classes, reduced size at age, associated with temperature size rule

Larocque. 2020.

* Focused on brown trout and Atlantic salmon juvenile dietary preferences in lake Ontario tributaries. Not sure how useful it is in terms of this literature review

Devi Tachamo Shah et al. 2020

* Not super helpful for this particular literature review

Jones (2008)

* Basically there are tradeoffs in the scale of taxonomic resolution used
  + Consider the purpose of the study
  + The end of the paper has some good recommendations

Bowman, M. F., & Bailey, R. C. (1997). Does taxonomic resolution affect the multivariate description of the structure of freshwater benthic macroinvertebrate communities? Canadian Journal of Fisheries and Aquatic Sciences, 54, 1802–1807

* Genus and family order taxonomic resolutions yielded similar assessments of community structures

Lento et al. 2022

* Warming in arctic regions is expected to result in the extirpation of uncommon taxa and movement North of taxa from lower latitudes
* They found Rarefied alpha diversity decreased with increasing latitude (and DECREASING temperature)
  + The relationship was stronger between temperature and rarefied α diversity than latitude and rarefied α diversity
  + Temperature gradient of 20 C to 1 C
  + Used long term average maximum august air temperature from 1970 to 2000 as their metric of temperature at each site
  + Temperature was positively correlated with most taxa
    - Taxa metric was Presence/Absence of the taxa
      * Used family level of classification
* Temperature was a strong predictor of community composition
  + High latitudes were chironomidae and Oligochaeta dominant
  + Lower latitudes had greater abundances of EPT
* Climate change is expected to increase BMI diversity in arctic regions as species move north.
* Used long term average maximum august air temperature from 1970 to 2000 as their metric of temperature at each site
  + - Air temp was considered reasonable proxy for water temp (yang et al. 2021)
    - Yang, D., Park, H., Peterson, A., & Liu, B. (2021). Arctic river water temperatures and thermal regimes. In D. Yang, & D. Kane (Eds.), Arctic hydrology, permafrost, and ecosystem: Linkages and interactions (pp. 287–313). Springer Nature.

Culp, J. M., Lento, J., Curry, R. A., Luiker, E., & Halliwell, D. (2019). Arctic biodiversity of stream macroinvertebrates declines in response to latitudinal change in the abiotic template. Freshwater Science, 38(3), 465–479

* + Used long term average of maximum august temperatures between 1971 and 2000 as their temperature metric
  + Higher latitudes had reduced taxonomic richness
  + Land cover type was also influential in determining community composition
    - Also alkalinity, total phosphorus, and total nitrogen
  + Communities in high arctic sites were positively associated with glacial sources and negatively associated with mean max august temperature
  + EPT taxa disappeared at higher latitudes
    - Most high latitude taxa were Chironomidae
      * 80% Chironomidae at 81 degrees N
      * abundances of Chironomidae and ephemeroptera at 58 degrees N were close in magnitude
      * 58 N had 4 families of Ephemeroptera, 4 families of Plecoptera, and 6 families of Trichoptera.
      * 63 N had few EPT taxa
      * 81 N had no EPT taxa
  + richness decreased at high latitudes, though total abundance (count of individuals) increased
* Phillips et al 2015 USE IN DISCUSSION OF IMPACTS TO ABUNDANCE
  + Hypolimnetic dam release cools reach of south Saskatchewan river below dam
    - Downstream reaches increased in temperatures more slowly, reaching lower maxima, and lagged behind reference reaches during fall drops in temperature
    - The downstream reach was 9 C cooler than references from May through July
  + Assessed changes in BMI community structure
    - Used other reaches unimpacted by dam’s thermal pollution as reference reaches for comparison
  + Summarized BMI community with:
    - Shannon diversity, richness, evenness, functional feeding group, and % EPT
    - Compared reference and test sites with ANOVA
  + In soft sediments
    - **Taxa richness and diversity decreased below the dam**
    - **Density of BMI was greater**
    - % predators shredders and scrapers increased
  + In hard sediments
    - **richness, diversity,** and evenness **decreased**
    - % EPT decreased
    - **Density increased downstream**
    - %shredders were higher, %filterers predators and scrapers were lower
  + Hexagenia limbate were absent below the dam
    - Water was too cold to generate enough degree days for the species life cycle
  + chironomids and oligochaetes increased in the abundance in the thermally polluted reaches downstream of the dam

Kishi et al. 2005 USE IN DISCUSSION OF IMPACTS TO FISH

* Fish (when present in high densities) exerted a top down effect on BMI when temperatures were near their thermal optima
* Above and below this optima they did not limit BMI biomass
  + Dolly Varden krill consumption rates were highest at intermediate temperatures
  + Glossosoma foraging activity was greater at moderate to high temperatures relative to low temperatures
  + Periphyton production was greater at warmer temperatures
    - In experiments with fish, periphyton abundance was higher a moderate temperatures as the predators reduced the caddis population and reduce the amount of grazing occurring
  + So as temperatures exceed salmonid thermal optima we would expect to see reduced control exerted on prey populations
* So a key take away here is changes in BMI communities may impact fish more at conditions near the fish’s thermal optima?????
  + Outside the optima, they are not limiting the food source anyway
* For coldwater adapted fish, changes in temperature could result in large changes to community structure due to trophic cascades as a results of their changing feeding rates
* USE IN DISUCSSION OF BEST PERFORMING METRICS
* Ott and Maret (2001). Aquatic Assemblages and Their Relation to Temperature Variables of Least-Disturbed Streams in the Salmon River Basin, Central Idaho, 2001
  + Compared 9 stream temperature metrics
    - Correlations between metrics were between 0.70 and 0.99
  + Directly from text
    - “MDMT Maximum daily-maximum temperature, in degrees Celsius
    - MDAT Maximum daily-average temperature, in degrees Celsius
    - MWMT Maximum weekly-maximum temperature. Derived from 7-day moving average of daily maximum temperatures, in degrees
    - Celsius MWAT Maximum weekly-average temperature. Derived from 7-day moving average of daily average temperatures, in degrees Celsius
    - MWMTS Maximum weekly-maximum temperature for date of sample collection. Derived from 7-day moving average of daily maximum temperatures on sample date and 6 days prior, in degrees Celsius
    - MWATS Maximum weekly-average temperature for date of sample collection. Derived from 7-day moving average of daily average temperatures on sample date and 6 days prior, in degrees Celsius
    - MAX∆T Maximum of the maximum daily temperature minus minimum daily temperature (diurnal fluctuation) for deployment period, in degrees Celsius BIG∆T Maximum daily-maximum temperature minus minimum daily-minimum temperature for deployment period, in degrees Celsius
    - DEGDAY Seasonal degree-days. Derived as sum of differences between daily average temperature and base temperature of 0 degrees Celsius for period July 1 through August 31, 2001”
  + Table 8 is really interesting. Shows correlations between the stream temperature metrics and various environmental variables
* Table 5 shows that community composition changes with temperature
* **Table 5 shows that different BMI taxa had different strengths of correlation with different temperature metrics**
* **Coldwater taxa was negatively associated with all temperature metrics**
* **Best performing temperature metric was variable and depended on taxa**

Waite. 2020 USE IN DISCUSSION OF CHANGES IN COMMUNITY COMPOSITION

* Assessed PNW streams across land use gradient
  + Puget sound basin and Willamette basin rivers
* Temperature was top variable influencing BMI composition
  + Assessed with Gradient Forest Model
  + Community composition was impacted by temperature
* They observed a reduction in sensitive coldwater EPT taxa
* Table 1 lists correlations for the more common invertebrates with temperature

White et al. 2018

* Climate Change impacts to BMI in Columbia River watershed
* Has some good background sources for expected climate change impacts
* Other than that, not very useful. More about planning rather and a moderate literature review than an actual study

Hubler et al. 2024

* Examined relationships between modeled stream temperatures and BMI in Oregon and Washington
  + Used Maximum Weekly Maximum Temperature (MWMT) which is an indicator of conditions of highest thermal stress
* Developed a Macroinvertebrate Thermal Tolerance Index (MTTI)
  + R squared of 68%
  + Temperature is one factor determining species compositions due to its impact on metabolism (Brown et al. 2004)
  + Table 2 gives great information on taxa common in different thermal regimes in the Pacific Northwest
  + Most coldwater and coolwater taxa belonged to EPT orders, but certain dipterans including chironomids were also common
  + Fine scale taxonomic resolution was most thermally sensitive
    - Even at the genus level, most genera with multiple species had species with different thermal optima
      * 16 of 17 genera with multiple species had species with different thermal preferences
  + The most thermally sensitive or tolerant taxa were best at distinguishing different thermal regimes (here defined with MWMT)
* Lusardi et al. 2020 USE IN DISCUSSION OF IMPACTS TO FISH
  + Juvenile Coho absolute growth rates were highest during a mean daily temperature of 16.6 Celsius (with a maximum weekly maximum temperature (MWMT) of 21.1 Celsius)
  + BMI Density was the main variable explaining juvenile coho growth rates
  + High prey abundances/densities can offset climate change effects of increased water temperatures
  + Assessed several temperature metrics
    - Maximum weekly average temperature (MWAT)
    - Maximum weekly maximum temperature (MWMT)
    - And Maximum Weekly Minimum Temperature (MWMinT)
  + Growth rate increased with BMI Density
  + Mortality rate increased with MWMT
  + Growth rates were still positive even at highest temperatures (Mean daily temperature of 18.1 C and MWMT = 24.0 C)

Brett 1982 USE IN DISCUSSION OF IMPACTS TO FISH

* Fed juvenile Chinook salmon to satiation Iab
  + Growth maximized at 19 Celsius
* Natural source populations fed about 60% of maximum, with an estimated corresponding temperature for optimal growth of 14.8 Celsius

Tate and Heiny 1995

* 21 sites in South Platte basin
* Collected BMI during summer low flow
* Not sure how helpful this source is in and of itself

Ward and Stanford (1982) USE IN DISCUSSION OF EMERGENCE AND GENERATIONS

* Temperature cues growth, development, and emergence
* Higher temperatures can advance or delay emergence, depending on whether warming or cooling water temperatures are a cue for emergence.
* Some species inhabiting different regions are found in different ecosystem types and thermal regimes (see reference 61 of this review)
* Number of generations may be influenced by temperature (voltinism)
  + Some species will experience more generations in warming conditions or fewer generations in colder conditions
* Temperature influences feeding rates and rates of processing of inputs of organic matter to streams (see references 2 and 160 of this review)
  + Examine these references in this literature review and add to references time permitting, but for now just citing the review….

Arai et al. 2014

* Plecoptera density decreased with higher mid-summer temperatures (July and August)
* Also provides a useful general citation for climate change predicted increases in air temperatures from IPCC
  + Temperature metrics included mean, max, std deviation, maximum increase, maximum decrease, maximum change, and water temperature per month
  + They took monthly water temperatures
  + I’m not entirely clear for the max increase/decrease/change if this is a daily, within a month, over the season, etc. Don’t understand timeframe here.
* Plecoptera density, EPT density, and taxon richness were all highly correlated with temperature
  + Maximum temperature performed slightly better than mean summer temperature
  + EPT and Plecoptera density declined with increasing temperature
  + Taxon richness also declined with increasing temperature
* Maximum temperature explained 82% of the variability in Plecopteran density
* They found mean taxon richness decreased with increasing water temperature
  + This is contrary to some other studies so additional variables may impact things, or different biomes may exhibit varying trends…
* They found richness was not correlated with altitude…. R squared was 0.26
  + But there could be some interactions among variables measured or unmeasured…

Jacobsen, D., R. Schultz & A. Encalda, 1997. Structure and diversity of stream invertebrate assemblages: the influence of temperature with altitude and latitude. Freshwater Biology 38: 247–261.

* Maximum stream temperature explained most of the variability in community structure
* BMI Order and family richness increased with maximum stream temperature
  + But they assessed different altitudes and this may present a confounding variable to some extent
  + This seems like a fairly high classification level to stop at….
* Examined 3 Ecuador streams and 1 Danish stream
  + These streams are on entirely different continents though with drastically different evolutionary and ecological histories
  + They even acknowledged significant substrate differences between the Danish and Ecuadorian streams…
  + Measured chemicals were different between the types though not significantly correlated with richness…
    - What about unmeasured chemicals
    - They measured conductivity, alkalinity, pH,
      * This is barely anything, also measured 3 times at each stream in the Ecuador sites, but just once in Danish site
      * Danish sites were measured in March, Ecuador streams measured in dry season, these are very different temporally, there are a lot of confounding issues with this study.
* Swartz and Warren 2022 MAYBE TALK ABOUT IN FISH AND FOOD WEB IMPACTS SECTION?
  + Assessed Mckenzie river Oregon tributaries pre and post burn
  + Assessed daily mean, daily max, and daily range in temperature
  + Chlorophyll a accrual increased 415% at burned sites post fire (and these sites also had substantial increases in daily mean, max, and range in temperature
    - Primary production impacts
* One question is how reliant are salmonids on sensitive EPT taxa as a food source versus other sources of food?