Climate is changing and seasons are becoming less predictable

* Average temperatures are rising
  + To what degree
  + higher daily temps
  + all seasons are warmer
* Average precipitation is variable
  + To what degree
    - Droughts and floods
* CO2 is increasing
  + To what degree
* Ocean temps are rising
  + To what degree
* Result of all these changes
  + Seasons less predictable Importance of temperatures and seasonal predictability
  + Environmental changes
  + How have we used this predicitibitlity in the past
  + What are the concerns moving forward under these conditions?

Changing climate effects populations

The effects of climate need to be investigated

Climate change and insect life histories

Effects of changing climate on insects

Different ways insects can respond to changing climate and why

* Relationship between climate and insect response to climate
  + Death
  + Migration
  + Adapt
    - Phenotypic plasticity in response to climate

Dormancy as a means of response and how this works

* Describe types
* Diapause (phenotype, uses, and how it is effected by climate, and reason to study diapause and how ECB is useful)
* Interaction between diapause and climate
  + Photoperiod, clines, how temperature effects this synchrony

Diapause physiology

The different ways insects respond to changes in climate is predicated upon an insect’s ability to sense a changing climate and the degree to which it is able respond to those changes.

*(use the butterfly example here or that nature paper). shifts and either fail to sense those changes or will be unable to respond to those changes. (examples of this type of null response to climate change in non-migratory species).*

Evo of diapause

Ecology of diapause

Things that are intimated do not need repeating. Cut to the idea of what diapause is and the effects of diapause. Do not qualify with the alternate.

Be more linear bread crumbs… step through climate, the impact on ecology, the effect on individual organisms and spepcies, then talk about how insect deal with those things trough diapause.

ECB: corn borers and genotypes. Isoforms, clines,

Objective: many pack on more reserves to diapause

Simplify hypothesis understanding reserve storage and understand diapause and physiology

Intro:

1. Climate is changing and This is how climate is changing
   1. Temperatures
   2. Predictability
2. Insects are changing (because of climate) and this is how they are changing
   1. Spatial distribution of insect
      1. How are these distributions changing
         1. And its effect on agriculture
   2. Phenotype changes
      1. how are phenotypes changing
3. synchrony between insects and climate is being effected
4. Some insects that can adapt are doing so by…
   1. Changing spatial distribution
   2. Phenotypic plasticity
      1. Evolving and compensating

This tends to be Insects could respond to the general warming of global temperatures, insects whose life histories are limited by lower temperatures could see an overall poleward shift in range distribution. This is has been observed in 35 species of European butterflies and increase in voltinism (the number of generations per year) (Bebber 2015). However, these generalisms do not account cause a net increase in range distribution and annual generation output (). will can have devastating effects on agricultural output produce different responses in effects on different species depending on how While some species will be unable to adapt to the changes in climate, These higher temperatures can have a range of effects on the population dynamics of species and these effects are dependent upon the sensitivity of a species to these factors.

The climate is changing dramatically and has been doing so over the past four decades (Mac et al. 1998). Historically, climate and seasonal temperature variations have been more predictable and organisms gradually flowed into different habitats and occupied new niches over time. In the context of a less predictable climate, organisms are thrown into different ecological spaces where the pressure to survive under novel conditions results in ecological upheaval. The ecological consequences of these dramatic climate fluctuations, must be investigated to fully understanding the degree to which these climate fluctuations will affect ecological stability and global food security.

Corn here in the United States is an important economic agricultural commodity. Agriculture output adds $136.7 billion dollars to the nations economy, accounting for 1% of the United States GDP in 2015 (Glaser 2016). For many farmers and consumers,

[ Expected effects of climate change on food security: DOI: 10.1038/ncomms6989]

* Parameter of food security
* Food security projections in the context of climate change
* pest pressure, degree days, crop yield as points

[ Expected effects of climate change on ecological diversity: DOI: 10.1046/j.1365-2486.2002.00451.x]

* Parameter of diversity
* Diversity as a function of reliability of seasons
* Population, location, and gradient of diversirty and specialists

**Ecological Result of Climate Change**

[ How organisms/insects adapt to climate change: doi: 10.1073/pnas.241391498]

* Removal of resources/hosts
  + Seasonally or permenantly
* migration
* “host switching?”
* plasticity

**Insect Diversity:** This effect is becoming more noticeable in regions where temperatures are less variable but extreme. For instance, in Antarctica (Find the Denlinger paper on that small insect losing its habitat). (Obligate lifestyle, specialized physiology, fragile ecosystem) Beyond simply losing acreage of habitable terrain, this species population will eventually decline to an unmaintainable number, making this and other species like it that live on the temperature extremes, causalities of climate change.

Farther away from these temperature margins, the interplay between temperature and organismal diversity is less conspicuous. (Reference the Sinclair paper and the William’s paper, discuss how there are alternatives to the dogma that climate change will diminish insect diversity.)

As environments continue to change and as seasonal temperatures become warmer and less predictable, organism diversity by some measures is declining. Ultra-cold temperature organisms are losing acres of habitat every year as these icy places become warmer. Reciprocally, ultra-hot environments are increasing in size as rainfall becomes more sporadic. These dry, hot places are also losing diversity to desiccation and heat exhaustion. Organisms that exist on these extreme margins have a more difficult time dealing with these biologically fast changes in their environment due to their extremely specialized lifestyle. As a result, some of this extremophile diversity could be lost as climate continues to change.

On the contrary, these environmental shifts do not necessarily spell disaster for all diversity, in fact organism diversity could increase in some environments (Sinclair 2015). This type of survival will depend largely on species genetic traits and phenotype plasticity (Williams et al 2014). **Animals and Climate:** Prior to the industrial revolution of the 19th century annual seasons followed a reliable pattern of high temperatures during the peak of summer and low temperatures during the peak of the winter. Associated with these cyclic temperatures was the waxing of daylight hours leading to the middle of the summer, and the waning of those hours leading to the middle of the winter. Both plants and animals have evolved to live in synchrony with these annually cycles and in many cases organism life histories have become constrained by them. In the Southern ocean, the ultra low temperatures freeze the sea water into a semi solid matrix. The sea ice matrix is crossed by a network of extremely brine filled passages, and within those passages microorganisms thrive (Thomas and Dikemann 2002). These tiny plants and animals have evolved to tolerate the habitat extremes of the free water of the Southern ocean and the semi-solid salty sea ice matrix. In fact these microorganisms living in the sea ice of the Southern Ocean rely on the ultra-low temperatures and predators, like krill, depend on the seasonal melting of the sea ice as a food resource. Such that changes to the pattern of freezing and thawing could potentially have cascading effects on the grazing and life histories of these lynch-pin predators.

In these extreme environments there is a tendancy towards obligate synchrony with the environment.

Temperate climates too have organisms with life histories that are “seasonal obligatory”

Temperate climates also have organisms with life histories that are “seasonally facultative”. Making predictions about these types of environments is important because it could mean [plant growing seasons, pest growing seasons] In more temperate environments….. [diversity, insect ranges, agriculture]

With annual temperatures are becoming more variable, those synchronized life histories are in jeopardy of unraveling. predicting how plants and animals will respond to these changes needs to be investigated further. For centuries, in the more temperate areas of the globe, those temperature drops coincide with the reduction of daylight hours. Plants and animals have evolved over millennia alongside these annual environmental changes and over time those organism’s life histories become dependent upon detecting those changes. Breaking the

**Adaptative Plasticity** [ How plasticity can mitigate effects of climate change: doi: 10.1111/brv.12105, doi:10.1093/icb/icr049, INSECT SEASONAL CYCLES: 195 GENETICS AND EVOLUTION]

* Parameters of plasticity: types and functions
* Buffer to Fluctuations and depleted resources
  + Diapause as an example
* ECB as an example

**ECB as a model** [ Importance of ECB to food security and ecological diversity]

* Agricultural importance [Host-plant diversity of the European corn borer Ostrinia nubilalis: what value for sustainable transgenic insecticidal Bt maize?]
  + Cost to protect
  + Ability to destroy
  + Current range and projections
* Latitudinal distribution [DOI: 10.1111/j.1365-2486.2010.02308.x]
  + Climate seems to have distributed these species. This is a chance to make interesting science
  + Clines are distributed latitudinally and are separated genetically
* Predictive power of model
  + Diapause phenotype and genetic differences
* **Notes:**
* PPT CPP Paper
* Fig 2a: temperatuiures are preduictably fluctuating. Given the CPP of 10C the certain points of the year the and organisms have optimized their physiol to match that predictability. Once their critical photo period is reached they begin preparations for diapauses. Under a changing climate scheme, there is a disconnect between CPP and temperatures. Organisms that are physiologically preparing for higher temps, conduct their preparations for those higher temperatures. To what degree those preparations will effect their performance during diapauses needs to be investigated to fully predict how climate chage can affect insect life history, survival and the resulting pest pressure changes.
* Does the fuel at the outset of diapause maybe determine how an insect performs during diapause?
* Organisms constantly are monitoring their internal environments and using that information to make physiological decisions about how to either store or utilize resources.
* Genotype variation based on season length and how this may change in light of climate change. Discuss why this is important
* Consider your project in the context of applied pest management. Your audience is the Ent department, Hahn and the USDA. More applied and more modeling
* For centuries, plants and animals have experienced the global climate in annual cycles. Organisms have evolved in the context of these annual cycles for millennia and as annual temperature fluctuations fall out of synchrony with daylight hours, understanding the consequences of this variability is urgent. What’s more is these organisms have come to depend upon these annual patterns, some more than others. Understanding the extent to which those relationships will be affected by this record setting unpredictability is a challenge that is sure to have broad effects on how we manage agricultural pests and our food security as a nation.

1. Adaptations to Climate
   1. Some losers
      1. Extinctions,
      2. reduced variability
   2. Some winners