***Revised Abstract:*** Diapause is a genetically determined life history strategy commonly used by many insects in temperate regions to avoid low temperatures and scarce food resources during winter. To meet the energy demands of their metabolism, insects often accumulate greater energy reserves before the onset of winter. Moreover, after diapause ends, some insects rely on that same pool of stored energy reserves to complete metamorphosis, find mates, and reproduce. However, the different ways temperate-insects manage nutrition in preparation for diapause and during diapause remains obscure. Using *Ostrinia nubilalis* (Hubüner) reared in conditions that induce diapause and measuring lipid storage, my goal was to determine the degree to which different diapause genotypes (long-diapause and short-diapause) affect nutrition accumulation in preparation for diapause and nutrition depletion during diapause. The combined effects of diapause genotype and diapause programming on lipid accumulation are clear; European corn borers increase lipid stores when programmed for diapause and these stores are highest in larvae with the long-diapause genotype. However, lipid depletion during diapause does not appear to be affected by diapause genotype. Reducing lipid stores before the onset of diapause could limit energy available to fuel metabolic activity during diapause and is one way to *manage O. nubilalis* pest populations. Before using the diapause genotype as a target of pest management, more research must be done to better understand the relationship between nutrient management, diapause length, and overwintering survival.

**Chapter 1: Introduction:**

* Seasons
  + Seasons bring variation
  + Seasonal dormancy synchronizes insects to seasons
  + Climate change will make seasons less predictable and **could** disrupt synchrony
* Response of insects to seasons
  + Winter is challenging
  + Diapause offers protection
  + Environmentally programmed
* Managing diapause
  + Physiology
  + Nutrient demand
  + Energy source and sink
  + Mismanaging diapause
* Project
  + Study: nutrients and diapause
  + Test: measuring lipids before and during diapause
  + ECB as a model

***Chapter 1 Revised:*** What are the factors that affect dormancy and life history timing? How do animals synchronize their life history with seasonal variation? To what degree does environmental variation alter phenotypes? In temperate regions, seasons cycle predictably between favorable spring and summer and unfavorable fall and winter. Winters in temperate regions are cold, dry, and nutrition is unavailable. Some insects in these regions have evolved seasonal dormancy (diapause) as a strategy to protect themselves from the unfavorable winter environment. Diapause is an alternative life history trajectory that is induced before the start of unfavorable conditions that leads to major physiological changes. There is substantial genetic variation in diapause-associated life history traits both within and among species. Variation in diapause traits may serve to synchronize insect life histories with predictable seasonal change. Genetic variation in diapause is also critical for diapause to evolve by natural selection. Climate change can lead to disruptions in diapause-mediated life history synchrony between insects and their environments as seasons become less predictable. Insects that are successful or are positively impacted by the warmer temperatures and longer growing seasons associated with climate change could be termed "winners" and insects that are negatively impacted by warming temperatures and shifting seasons could be termed "losers". Genetic variation in diapause traits could prove to be beneficial as climate changes and seasonality becomes less predictable.

In temperate regions, warm temperatures persist in the spring and summer. During the warm season, insects use available food and water to grow, develop, and reproduce. As temperatures decline in the fall and winter, resources become scarce. For insects in temperate regions, low temperatures can greatly reduce metabolic activity making continued activity challenging or even impossible. To overcome the challenges faced during winter, many temperate dwelling insects use diapause. Diapause is a genetically regulated and environmentally influenced alternative developmental trajectory initiated before the onset of winter and during a species-specific life stage [1]. By monitoring environmentally consistent cues that cycle with seasonality, insects can reliably predict, prepare for, and protect themselves from unfavorable changes in seasonal temperature and resource availability by initiating diapause. To predict seasonal change, temperate insects generally use photoperiod alone or in concert with other environmental cues, like temperature or host-plant quality, to induce diapause before arrival of prolonged seasonal stress.

The onset of diapause is generally marked by the suspension of development, a reduction in metabolic activity, and during diapause many insects do not feed [1, 2, 3, 4]. However, diapausing insects must continue to meet the energetic demands of their metabolism during diapause. In addition to the added energy cost incurred by surviving winter in diapause, insects exiting diapause must also have enough energetic and anabolic resources left to resume development. In preparation for diapause many insects store additional lipids to use as fuel during diapause, however nutrition is also stored in the form of carbohydrates and proteins [3, 5]. For insects that use diapause, the decision to switch developmental trajectories, the timing of diapause induction, accumulating enough nutrition during diapause preparation, and the rate stored energy is depleted during diapause are each crucial to its survival. If the onset of diapause occurs before the favorable season ends it will limit an insects ability to take advantage of available resources. Early entry into diapause could also lead to the premature depletion of stored nutrients as metabolic activity during diapause relies on stored energy. If the onset of diapause is late and occurs after the unfavorable season begins an insect could be exposed to conditions that could cause mortality.

The goal of this study is to characterize the relationship between nutrition storage and diapause genotype. Using two strains of Ostrinia nubilalis (European corn borer) with different diapause genotypes, I tested the degree to which diapause genotype affects nutrition storage. Specifically, I tested the degree to which diapause genotype could be associated with lipid storage during diapause preparation in European corn borer. I expected insects with a longer diapause genotype to store more lipids than insects with a shorter diapause genotype in preparation for diapause (1-1A). The European corn borer is suitable model to investigate the relationship between nutrient accumulation and diapause length because it is an important insect pest with sympatric populations that are genetically distinct and express diapause phenology that differs in length.

**Chapter 3: Background outline**

* Environments and Insects
  + Variation
  + Stress
    - Synchrony with variation and stress
      * Dormancy: quiescence and diapause
        + Diapause
* Climate change and Insects
  + Response of pests to Increased temperatures and longer seasons (Losers v. Winners)
    - Higher temperatures
      * Impacts
        + Population range

Butterfly Example

* + - * + Thermal performance

Deutch Example

* + - * + Adaptation

Plasticity vs Adaptation

Bradshaw example

* Diapause Generally
  + Induction
  + Maintenance/Metabolism
    - Fueling diapause: nutrition stores
* Modeling response of nutrition to season length
  + Goal
  + Test: Lipid stores
  + Model: ECB
  + Predictions/Outcome