CHAPTER 3 EUROPEAN CORN BORER: THE RELATIONSHIP BETWEEN STORED RESOURCES AND DIAPAUSE TIMING

3.1 Background

According to the National Oceanic and Atmospheric Administration, 2016 was the warmest year on record and temperature increases are expected to continue through the year 2100 [25, 26, 27]. As seasonal temperatures increase, the duration of warm summers will expand, cool winters will contract, and temperatures during the spring and fall will become less predictable [28, 29]. Animals monitor variation in seasonal factors like temperature and photoperiod (daylight hours) because these factors can affect the availability of nutrition, mates, and habitat. Seasonality predictably cycles between conditions that are favorable for insect activity and conditions that are stressful and unfavorable. Many temperate-dwelling insects protect themselves from seasonal stress by entering diapause before their environment becomes unfavorable [1].

Insects in diapause can survive for months exposed to harsh conditions and typically do so without access to nutrition by lowering their metabolic activity and suspending their development [30, 3]. Before the environment becomes unfavorable, insects prepare for diapause by accumulating and storing nutrients in the form of lipids, proteins, and carbohydrates [1]. For example, increased energy storage in the form of proteins has been reported in Colorado potato beetles (*L. decemlineata*) (Kort and Koopmanschap 1994) and southwestern corn borers (*D. grandiosella*) (Brown and Chippendale 1978), while increased lipid storage has been reported for the pink bollworm (*P. gossypiella*) (Adkisson et al. 1963) and *Culex pipens* mosquitoes (Mitchell and Briegel 1989), among others. Energy stores fuel insect metabolism during diapause, and after diapause these stored resources are redirected to accomplish post-diapause functions. However, metabolic activity for many insects is temperature dependent and insects preparing for diapause in warmer environments may struggle to meet the energy demands of an increased metabolism and possibly divert resources away from storage.

Insects entering diapause without adequate nutrition stores may exit diapause before winter ends leaving them exposed to an unfavorable environment and thereby increasing mortality. A study using *Calliphora vicina* (Robineau-Desvoidy) as a model explored the effect of nutrition on the duration of diapause [44]. While preparing for diapause, the diet of some larvae was restricted. The authors found that when diet was restricted larvae entered diapause with less mass and remained in diapause for a shorter period than larvae given an unrestricted diet [44]. Insects that exit diapause early could be exposed to stressful low winter temperatures or they may not have enough stored nutrients and other metabolic substrates remaining to meet the anabolic requirements for post-diapause development, metamorphosis, repair, and other post-diapause activities like reproduction [3, 4].

Climate change could also decrease levels of stored nutrition in diapausing insects as warmer and more variable fall and winter temperatures increase insect metabolic activity [31, 32, 33, 4]. These researchers held diapausing *Diatrea grandiosella* Dyar moths in warm temperatures and compared lipid mass to moths diapausing in cool temperatures. The moths that were exposed to the warmer temperatures also demonstrated a significant decrease in lipid stores at the end of diapause compared to moths in cooler conditions [Thompson and Davis 1981].

Warmer temperatures during diapause preparation could increase metabolic rates and could redirect resources away from nutrient storage. Being unable to build up enough stored energy before the onset of diapause could limit an insect’s ability to enter diapause before the onset of winter. Similarly, warmer winter temperatures could also increase the metabolism of diapausing insects, causing them to deplete stored energy before environmental conditions become favorable for development the next spring, leading to mortality. Surviving diapause with reduced resources could also affect adults post-diapause and limit critical functions like dispersal, mating, and reproduction.

*Ostrinia nubilalis* (European corn borer) is an excellent model to understand how warmer fall temperatures might influence nutrition storage ahead of diapause, as well as the role of warmer winter temperatures on energy depletion during diapause. European corn borers exist as at least two naturally segregating, genetically distinct strains with unique diapause genotypes. Regardless of genotype, these two strains can and do occur at the same latitude and experience the same fall and winter, however the diapause genotype of each strain expresses a specific length of diapause. Larvae with the "long-diapause" genotype experience a warmer, longer diapause because they enter diapause earlier in the fall and exit later the next spring. Alternatively, larvae with the "short-diapause" genotype experience a shorter, cooler diapause because they enter diapause later in the fall and exit earlier the next spring. Comparing nutrition storage strategies between these two strains could build our understanding of how insects might adjust to warming winter temperatures as Earth’s climate changes.

Adjusting to climate change for some insect species may be difficult because warmer seasonal temperatures could lead to reductions in population size or extinction. European corn borers with the short-diapause genotype could provide an example of how climate might negatively impact insect populations if warmer diapause temperatures drain nutrient stores prematurely and these larvae exit diapause before seasons change. However, the effects of climate change f could also be positive for some insects. If the effects of warmer diapause temperatures can be mitigated by larger nutrient stores, then insects that utilize this strategy like long-diapause European corn borers could thrive.

Warmer fall temperatures experienced by the two strains of European corn could lead to increased metabolic activity and in turn increase the share of energy required to fuel their metabolism ahead of diapause. During diapause, both strains rely on stored nutrients to fuel their suppressed metabolism and both strains experience the same thermal environment. Unless their metabolism is significantly influenced by diapause genotype, metabolic activity during diapause should be similar between the two strains. I predict the genotype that survives the longer, warmer diapause period will accumulate more nutrient stores prior to diapause compared to the genotype with a shorter larval diapause. However, during diapause, and regardless of diapause genotype, I expect that larvae will deplete nutrient stores at a similar rate. To investigate the relationship between diapause length and nutrient storage, lipid stores at the start of diapause and during diapause were measured in each strain. This research showed that larvae with the long-diapause genotype accumulated more lipid mass at the onset of diapause compared to larvae with the short-diapause genotype. However whether the rate of lipid depletion between the two strains differed during diapause was inconclusive.

References (To be added)