2.4. DISEASE AND PREDATION

The primary focus of this risk assessment is effects of the gypsy moth on other species. Nonetheless, many organisms may adversely affect the gypsy moth, thereby reducing the risks posed by gypsy moth infestations. The gypsy moth is susceptible to diseases, including diseases caused by pathogens like *B.t.k.*, the gypsy moth nuclear polyhedrosis virus (LdNPV), and *Entomophaga maimaiga* fungi. Bacterial pathogens in addition to *B.t.k.* and other *Bacillus* species that adversely affect the gypsy moth, include *Serratia marcescens, Serratia liquefaciens, Streptococcus,* and *Pseudomonas* spp. These microorganisms are associated with a collective mortality in the gypsy moth of less than or equal to 15% (Podgwaite 1981). The gypsy moth nucleopolyhedrosis virus (LdNPV) is a natural component of the gypsy moth environment (Podgwaite 1979; 1981; Podgwaite and Campbell 1970; Lindroth et al. 1999) and is considered the primary natural regulator of dense gypsy moth populations in North American forests (Glaser and Chapman 1913; Doane 1970). High density populations of gypsy moth will eventually collapse, for the most part due to pathogens, especially NPV (Elkinton and Liebhold 1990). *B.t.k.* and LdNPV are also control agents for the gypsy moth, and are addressed individually in separate risk assessments.

In addition to viral and bacterial pathogens, several fungal pathogens will infect gypsy moth populations, including species of *Paecilomyces*, *Fusarium* and *Verticillium* (Hajek 1997). Most fungal pathogens, however, appear to account for insignificant levels of recorded gypsy moth mortality (Podgwaite 1981). A major exception, however, is *Entomophaga maimaiga*, which plays an important role in gypsy moth population dynamics on other continents and which is widely established in North America. Nealis et al. (1999) estimate that *E. maimaiga* may account for approximately 4-14% of mortality in gypsy moth larvae. Infections with *E. maimaiga* tend to be more prevalent than naturally occurring infections from NPV in areas with low egg mass density (Buss et al. 1999). In low density plots, *E. maimaiga* increased mortality substantially only in 5th instar and later instars. In high density plots, earlier instars were also infected (Hajek 1997; Hajek et al. 2001). Models for the influence of *E. maimaiga* on gypsy moth populations have been developed by Weseloh (1998a, 1999, 2002, 2003).

The gypsy moth is at risk of significant predation by mammals, birds, and other insects. In general, invertebrates are the major predators of gypsy moth larvae, while small mammals are the major predators of pupae (Grushecky et al. 1998). Mice and shrews are important predators of gypsy moth, particularly during the pupal stage (Bess et al 1947; Jones et al. 1998) or when the population density of the gypsy moth is low (Elkinton et al. 1996, 2002). When the population density of small mammals is high, small mammals may be a major source of predation on larvae (Cook et al. 1995). When populations of small mammals are low, the relative importance of predation by terrestrial invertebrates increases (Hastings et al. 2002a,b).

Forbush and Fernald (1896) first identified birds as predators of gypsy moth larvae. Some species of birds even prey on egg masses (Cooper and Smith 1995). In general, however, mammals appear to have a greater impact on gypsy moth populations than birds (Smith and Lautenschlager 1981; Elkinton and Liebhold 1990).

Numerous insects act as parasites or predators to the gypsy moth, including the larvae of various tachinid flies and braconid wasps (Hajek 1997). Extensive efforts were made to introduce European and Asian gypsy moth parasitoids to North America (parasitoids are insects, especially flies and wasps, that complete their larval development inside the body of another insect). Ten species have become established (Elkinton and Liebhold 1990). Gypsy moth mortality due to each type of parasite is specific to a given gypsy moth life stage. The venom of the ectoparasitic wasp *Microbracon hebetor*, contains a toxin that inhibits larval growth in gypsy moth (Masler and Kovaleva 1999). The food preference of certain wasps species—i.e., chalcids—seems to depend on the sex of the pupae (Fuester and Taylor 1996). Although invertebrate predation of gypsy moth pupae may be minor compared with vertebrate predation (Campbell and Sloan 1977a), Smith and Lautenschlager (1981) suggest that mortality attributed to vertebrates may be caused by invertebrates, like ground beetles (Elkinton and Liebhold 1990). Both adult and immature stages of *Calosoma sycophanta*, a large ground beetle introduced from Europe, are known to feed on gypsy moth larvae and pupae (Elkinton and Liebhold 1990). In addition, Weseloh (1996b, 1998b) suggest that predation by ants, particularly on gypsy moth larvae that fall to the forest floor, could cause significant mortality to gypsy moth larvae.