The gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), is one of the most damaging pests of forests in its introduced range in North America and in its native distribution in temperate Europe, North Africa, and Asia (Fig. 1) (Giese and Schneider 1979, Montgomery and Wallner 1989). Over much of its range, gypsy moth populations periodically erupt to massive levels, causing extensive defoliation of broadleaf and coniferous forests. Many eruptions are spatially synchronized so that outbreaks occur concurrently over large geographic areas (Johnson et al. 2005, 2006), greatly exacerbating the economic and ecological costs associated with high-density populations.

In North America, gypsy moth life stages were introduced outside of Boston in 1869, and it has since expanded its range (Fig. 1) (Liebhold et al. 1989). Females of North American populations cannot fly, which limits its rate of spread; however, increases in its range can still exceed 20 km/yr (Liebhold et al. 1992, Tobin et al. 2007), mainly because of anthropogenic movement of life stages. Outbreaks in North America have been observed to occur about every 8–12 yr (Johnson et al. 2006).

In its native range in Europe, gypsy moth outbreaks are common, particularly in oak-dominated forests in the Mediterranean region. In the majority (but not all) of European gypsy moth populations, adult females are completely incapable of flight (Keena et al. 2008). The gypsy moth is also widely distributed through Asia, where there is tremendous variation in various biological traits among populations. Although most females are capable of flight in Asian populations, this is not the case in all areas (Keena et al. 2008). Also, populations across Asia appear to exhibit a broader range of host species. In addition to *Quercus* spp. (oak), which is the most common host in Europe and N. America, stands dominated by *Larix* (larch), *Tilia* (basswood), *Diospyros* (ebony), and *Populus* (aspen) spp. are capable of supporting massive outbreaks in Asia (Schaefer et al. 1984, 1988).

Although some information about Asian gypsy moth populations in Japan, Siberia, and China is available in the western literature (e.g., Schaefer et al. 1988), relatively little information exists about populations in Central Asia (Fig. 2). We address this deficiency by providing an introductory description of the biology and ecology of the gypsy moth in Central Asia. We first describe the habitat in this region, which contains native walnut–fruit forests and thus is unique relative to other portions of the gypsy moth’s range.

Central Asia Geography

In this article, we define Central Asia as the region covering Kyrgyzstan, Kazakhstan, Uzbekistan, Tajikistan, and Turkmenistan, extending from the Caspian Sea to the west, Mongolia and China to the east, south from the Ural Mountains and Siberia, and north from Iran and Afghanistan (Table 1, Fig. 2). This large region has varied geography, including high passes and mountains (Tien–Shan), vast deserts (Kara Kum, Kyzyl Kum, Taklamakan), and large and mostly treeless grassy steppes. The vast steppe areas of Central Asia are considered, together with the steppes of Eastern Europe, as a homogeneous geographical zone known as the Euro–Asian steppe. Much of the area consists of steep mountain ranges reaching 7,495 m in elevation, largely covered by rock and devoid of extensive vegetation. Lowlands stretch from north to south for more than 3,000 km, and there is a gradient from a mixed zone to a zone of deciduous forests to forest steppe and steppe zones and finally to semi-arid and arid zones. The climate is decidedly continental with a vast amplitude of summer and winter temperatures (Klein Tank et al. 2006). The region is rich in water resources that originate mostly from the winter snow pack in the mountains of Kyrgyzstan and Tajikistan that drains into the region’s two main rivers, Syr Darya and Amu Darya. All of the region’s rivers drain into the Aral Sea in Uzbekistan and Kazakhstan, which has no outlet and where all water eventually evaporates. During the Soviet era, large portions of these rivers were diverted for agriculture, causing a massive decline in the extent of the Aral Sea, which before 1960 was the forth largest lake in the world. In recent years, however, this trend has been partially reversed and the Aral’s level has increased although it has not yet reached its previous size.
Table 1. Characteristics of Central Asian countries (modified from FAO 2006)

<table>
<thead>
<tr>
<th>Country</th>
<th>Area (1,000 km²)</th>
<th>Population (1,000)</th>
<th>Forested area (1,000 km²)</th>
<th>Pistachio forest (1,000 km²)</th>
<th>Walnut–fruit forest (1,000 km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kazakhstan</td>
<td>2,700</td>
<td>15,200</td>
<td>33.4</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Kyrgyzstan</td>
<td>200</td>
<td>5,214</td>
<td>8.7</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Tajikistan</td>
<td>143</td>
<td>7,181</td>
<td>4.1</td>
<td>1.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>488</td>
<td>5,000</td>
<td>41.3</td>
<td>0.8–1.0</td>
<td>0.001</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>447</td>
<td>26,800</td>
<td>33.0</td>
<td>0.2</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Following the Bolshevik Revolution in 1917 and up to 1991, Central Asia was part of the Soviet Union, but it now consists of the independent republics of Kazakhstan, Uzbekistan, Turkmenistan, Kyrgyzstan and Tajikistan. Despite their unique histories, the Central Asian countries have similarities in their historical development, which is apparent through the spiritual and cultural similarity of Central Asian people. Central Asia contained much of the ancient Silk Route, which connected East Asia to southern Europe, and thus played an important role as a cultural and economic transcontinental link. In the 13th century, the Mongol empire of Genghis Khan extended over almost all of Central Asia. Various Mongolian leaders followed, but in later years the region was divided into smaller empires that were more regionally controlled. In the 18th century, much of Central Asia fell under the domain of the Chinese Qing dynasty.

The Russians began their conquest of Central Asia under Peter the Great in the 19th century, and Russian influence continued until the fall of the Soviet Union in 1991. For thousands of years before the formation of the Soviet Union, and even when under the domain of various empires and dynasties, the Central Asian people were predominantly nomadic. Their livelihood and culture revolved around herding animals, predominantly horses that are native to Asia. With the advent of the Soviet Union, however, a large proportion of the Central Asian population was settled on large collective farms. Following the collapse of the Soviet Union and consequent independence of the Central Asia states, most of these collective farms were dissolved, although most forest land has remained under government ownership.

As result of their history, Central Asian societies have been exposed to many cultural influences that have framed their customs and spiritual beliefs. However, because of its mountainous topography, Central Asian civilizations also remained highly isolated, and consequently societies in various regions have retained unique customs and traditions. The predominant religion in Central Asia today is Islam, which is thought to have arrived to the region in the 8th century.

The Forests of Central Asia

Despite the mountainous nature of Central Asia, forests cover a relatively small proportion of each country (Table 1) and broad-leaved species dominate only a small fraction of forests. Much of the forest area in Central Asia is dominated by saxaul (Haloxylon spp.) and other shrubs found particularly in desert and semi-desert areas of Kazakhstan, Turkmenistan, and Uzbekistan. In the moist, mountainous areas of southeastern Kazakhstan and northeastern Kyrgyzstan (the Tien Shan Mountains), there are extensive thickets of Betula (birch), Abies (fir), Populus (aspen), and Picea (spruce) spp. The spruce forests of Kyrgyzstan are composed of uneven-aged forest stands dominated by Picea schrenkiana Fisch (Musuraliev 1998), which grow in the mountain ranges surrounding Lake Issuk–Kul, the Naryn water basin of northern Kyrgyzstan, and in the Talas and Kyrgyz Mountain ranges in the south.

Juniper-dominated forests are concentrated in the southern part of the Turkestan–Alay forest vegetation area of Kyrgyzstan and these forests are composed primarily of Juniperus seravschnica Kom., Juniperus semiglobosa Rgl, and Juniperus turkestanica Kom. Historically, juniper was widespread throughout the valleys of Central Asia (Musuraliev 1998). Its current distribution, however, is sparse and confined to a narrow, discontinuous belt over mountain slopes at elevation range from 1,800 to 3,500 m. Riparian forests are located in mountainous areas along the Naryn, Chy, Tüp, Talas, Sysamur, Djergalan, and Yassu rivers, as well as many smaller rivers where they play a role in the regulation of water supply and protection against soil erosion. These forests are composed of various species such as Populus nigra, P. diversifolia, Salix alba, S. cinerea, Eleagnus angustifolia, Tamarix laxa, Hippophae rhamnoides, and Ulmus spp. The walnut–fruit forest is unique to Central Asia and grows above the steppe zone in warm, sheltered valleys in the western Pamir–Alai, Tien Shan, and Kopetdag mountains. The Tien Shan is the most recent mountain range to emerge from the collision of the Indian subcontinent with Asia during the Cenozoic era. Currently rising about 1.5 cm/yr, the Tien Shan has never experienced glaciations, and its highest peak is Jengish Chokusu in Kyrgyzstan (7,439 m). Snow-covered peaks provide abundant moisture to fruit forests in valleys (Juniper 2007). The main walnut–fruit species that occur naturally in Central Asia are Persian walnut (juglan regia), pistachio (Pistacia vera), apple (Malus sieversii, M. niedzwetzkyana), almond (Amygdalus communis L.), wild plum (Prunus sogdiana), wild cherry (Prunus ferganica), mountain ash (Sorbus persica), wild pear (Pyrus bucharica, P. korczinsky), and other fruit-bearing trees and shrubs.

The native range of Persian walnut extends from Nepal in the east, across Central Asia, to the Caucasus, and as far west as Turkey (Hemery 1998). The most extensive walnut forests are in Kyrgyzstan (Chatkal and Fergana Mountains), Uzbekistan (Chatkal Mountains), Turkmenistan (Kopetdag Mountains) and Kazakhstan (Ugam centre). In southern Kazakhstan the species is present, but
it does not form extensive forests; trees are scattered in small groves of 0.6 to 0.8 ha (Dzhangaliev et al. 2003). In Turkmenistan, walnut forests grow in Western Kopetdag in a 100-ha area (Allamuradov et al. 2005). In Uzbekistan, natural walnut forests cover 298 ha (Uzbek State Department of Forestry 2007).

Pistachio, *Pistacia vera*, grows under dry conditions of the semi-desert foothills of Central Asia (Fig. 3a, b). It is widely distributed throughout the Tien Shan foothills of the Kyrgyz Mountain range (42° 5′ latitude North). North Kyrgyzstan (on the foothills of the Kyrgyz mountain chain), Uzbekistan (the Pslam and Chatkal Mountain chains), South Kazakhstan (the Talas, the Alatau, the Karatau), and North Tajikistan (the Kuramin Mountain chain) are sparsely populated, and there are a few isolated stands of pistachio. In the Central Pamir–Alay region, pistachio stands are widely distributed in the southern Tajikistan (along the Pandj, Karatau, Teriklitau, Arooktau, Sarsharak, and Chaltau mountain ranges), eastern Turkmenistan (Koogitau), and southern Uzbekistan (the Babatag mountains) regions at an altitude of 500–1,800 m. In this region, dense stands are found at 800–1,200 m. Isolated pistachio stands grow near Kososkha in the South Kopetdag region of southwest Turkmenistan at elevations ranging from 600 to 1,000 m (Kaimov et al. 1998, Chernova 2004).

Wild stands of apple in Central Asia have received global interest because they are a reservoir of genetic diversity from which domestic cultivars may be drawn (Miller 2006). The species *Malus sieversii* Lebed. is native to Central Asia and is recognized as a major progenitor of the domesticated apple, *M. pumila* Mill. In ancient times, apple seeds and trees were likely transported from Central Asia into China to the east and Europe to the west across the Silk Route (Forssline et al. 2003). Phylogenetic studies show that wild apple (*Malus sieversii*) from Central Asia is quite similar to domesticated apples, and that several other *Malus* species are almost indistinguishable (Juniper 2007). Another important Central Asian apple species is *Malus niedzwetskyana*, which is an endangered species. Because of the potential importance of *M. niedzwetskyana* as a genetic resource, it is paramount to preserve it and other wild apple species from Central Asia.

**Forest Biodiversity and Sustainable Use**

There has been wide recognition of the tremendous importance of Central Asian walnut–fruit forests both as a genetic resource and as a source of biological diversity (Yazimirsky 1938, Shevchenko 1968, McGranahan and Leslie 1991, FAO 1995, Hemery 1998, Kolov 1998, Musuraliev 1998). These forests represent a unique ecosystem not found elsewhere in the world and they contain several woody plant species unique to the region. These forests are also dominated by nut-and fruit-producing tree species, many of which are relatives of species of eminent commercial importance worldwide (e.g., apple, pear, pistachio, and walnut). The preservation of genetic diversity from tree species that are unique to the Central Asian forests should thus be of global importance. Historically, the walnut–fruit forests have been important to the livelihoods of the rural people who live in and around them. Today, through the development of sustainable management practices for harvesting nuts and fruit, these forests have the potential to alleviate poverty.

Productivity of walnut ranges from 40 to 350 kg of nuts per hectare of forest, depending upon growing conditions (Shevchenko 1968). Yields of pistachio nuts from natural stands are rather low, ~1 kg per tree, although up to 15 kg per tree may sometimes be collected (Chernova 2004). The highest pistachio yields are typically obtained from 60–80-yr old trees, although trees will continue to produce nuts for >300 yr. Pistachio trees in natural stands typically occur sparsely scattered over grassland with densities of only 30–70 trees per hectare. Since the early 1980s, there have been efforts to identify highly productive pistachio strains and plant these in various portions of the foothill regions of the Central Asian steppe at elevations from 800 to 1,200 m to increase nut production.

The walnut–fruit forests are of considerable importance for sustaining the livelihoods of more than 100,000 people living in the forest area (Favre 1997, Schmidt 2005). The human population in these regions containing walnut–fruit forests has increased considerably over the past 50 years and created intense pressure on the limited natural resources. Collecting nuts and fruit is of immense economic importance for households in the region. In many areas, almost all of the nuts are commercially harvested, which essentially eliminates natural regeneration.

Historically, the mountain forests of Central Asia have been exploited for timber, fuel wood, and charcoal; however, recently these activities have intensified because of increased human settlement and the accompanying demand for timber and fuel. These practices, coupled with hay-making and overgrazing of cattle, sheep, and goats, have caused extensive destruction of forested areas, including the fruit–nut forests of Central Asia. In addition to the human demands for Central Asian forest resources, the gypsy moth places an additional burden on the sustainability and productivity of the fruit–nut forests unique to the region.

**The Gypsy Moth in Central Asia**

The fruit–nut forests of Central Asia have been and continue to be threatened by a remarkably sustained outbreak of the gypsy moth over the past 30 years. The gypsy moth is apparently native to Central Asia, where it is widely distributed (Pogue and Schafer 2007) (Fig 2). However, the Central Asian gypsy moth population is isolated from other Eurasian populations by deserts to the north, spruce forests in Tien–Shan to the northeast and east, and the Caspian Sea to the west. Little information is available about the distribution of the gypsy moth in southern portions of Central Asia, but it is likely that its patchy distribution continues from the high mountain valleys of Tajikistan into the Kashmir region of Pakistan and India. Central Asian gypsy moth populations could ultimately intergrade to the south with *Lymantria obfuscata* populations from India, Pakistan, and Afghanistan (Pogue et al. 2007).

The gypsy moth is highly polyphagous, and in North America larvae feed on more than 300 host tree species (Liebhold et al. 1995)
(Table 2). None of the genera most commonly defoliated elsewhere in the range of the gypsy moth (i.e., Quercus, Larix, and Populus) are native to Central Asia, nor are they commonly present in Central Asia today. Instead, most gypsy moth outbreaks in Central Asia occur in stands of Pistacia and Malus, although several other tree species are also known to be suitable hosts.

Reliable data on historical defoliation by the gypsy moth in the region are lacking but the first known record of an outbreak population in Central Asia dates back to 1938 in Kazakhstan (Gninenko 1986). Despite the lack of reliable data, our investigations indicate that gypsy moth outbreaks in Central Asia have become increasingly more extensive over the past two decades. In 2007 alone, several thousand hectares were defoliated, mostly in Kyrgyzstan and Kazakhstan.

The Role of Natural Enemies of the Gypsy Moth in Central Asia

A nucleopolyhedrosis virus (LdMNPV) occurs in almost every gypsy moth population worldwide, and it is considered to be a primary source of mortality and consequent outbreak collapse in dense gypsy moth populations. Based on limited information, it appears that LdMNPV plays a similar role in Central Asian gypsy moth populations (Orlovskaya 1968, Il'inykh et al. 2005). In 1983, the All-Russian Scientific Research Institute of Forestry and Mechanization, Pushkino, Moscow, built a laboratory for the mass production of LdMNPV in Djalalabat city, Kyrgyzstan. This laboratory operates today, and viral preparations from the lab are directly "painted" on the surface of egg masses in the field for management purposes, although the efficacy of this method is not well documented.

The fungus, Entomophaga maimaiga (Zycomycotina: Entomophthoraceae), is a common gypsy moth pathogen in Japan, where epizoicous are frequent. This pathogen was discovered in North America in 1989 and subsequently caused extensive epizootics in dense gypsy moth populations. Based on limited information, it appears that LdMNPV plays a similar role in Central Asian gypsy moth populations (Orlovskaya 1968, Il'inykh et al. 2005). In 1983, the All-Russian Scientific Research Institute of Forestry and Mechanization, Pushkino, Moscow, built a laboratory for the mass production of LdMNPV in Djalalabat city, Kyrgyzstan. This laboratory operates today, and viral preparations from the lab are directly "painted" on the surface of egg masses in the field for management purposes, although the efficacy of this method is not well documented.

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Table 3. Primary gypsy moth parasitoids established in the United States, and Central Asia

<table>
<thead>
<tr>
<th>Order: Family</th>
<th>Species</th>
<th>Established in the U.S.</th>
<th>Established in Central Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hymenoptera: Eupelmidae</td>
<td>Anastatus japonicus Ashmead</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera: Encyrtidae</td>
<td>Ooencyrtus kuwanae (Howard)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Ichneumonidae</td>
<td>Phobocampe unincincta (Gravenhorst)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Ichneumonidae</td>
<td>Phobocampe lymantriae Gupta</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Ichneumonidae</td>
<td>Pimpla instigator F.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Ichneumonidae</td>
<td>Pimpla turionellae (L.)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Ichneumonidae</td>
<td>Pimpla disparis (Vierick)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Ichneumonidae</td>
<td>Caenocryptus rufiventris (Gravenhorst)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Bracidae</td>
<td>Cotesia melanoscella (Ratzburg)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Bracidae</td>
<td>Glyptapanteles liparidis Bouche</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Bracidae</td>
<td>Dolichogenidea lactecolor (Viereck)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Chalcididae</td>
<td>Brachymeria intermedia (Nees)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hymenoptera:Diapriidae</td>
<td>Tetramopria aurocincta Wasmann</td>
<td>✓</td>
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</tr>
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<td>Diptera: Tachinidae</td>
<td>Compistus concinnata (Meigen)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Diptera: Tachinidae</td>
<td>Blepharipa pratensis (Meigen)</td>
<td>✓</td>
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</tr>
<tr>
<td>Diptera: Tachinidae</td>
<td>Parasitica silvestris (Robineau-Desvoidy)</td>
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<td>Diptera: Tachinidae</td>
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<tr>
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<td>Exorista larvarum (L.)</td>
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<tr>
<td>Diptera: Tachinidae</td>
<td>Exorista rossica Mesnil</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

and Fiske 1911, Burgess and Crossman 1929). Beginning in 1906, more than 60 species of egg, larval, and pupal parasitoids, predators, and pathogens were introduced, but most failed to establish (Hoy 1976). Only 11 parasitoids, two predators, and two pathogens became established, and among these several became major natural enemies of the gypsy moth in North America (Reardon 1981) (Table 3).

The species composition of parasitoids of the gypsy moth varies throughout Eurasia (Howard and Fiske 1911), although because of taxonomic difficulties (misidentification and synonyms), the number, relative importance as mortality factors, and geographical distribution of the various species are difficult to evaluate (Reardon 1981). A list of gypsy moth parasitoids that have been recorded from Central Asian gypsy moth populations is provided in Table 3. Almost every known gypsy moth parasitoid present in North America is present in Central Asia, although the reverse is not true. The one exception is Glyptapanteles liparidis (Hymenoptera: Braconidae) which is present in worldwide gypsy moth populations including Central Asia. Although its introduction has been attempted in North America, it failed to establish due to a lack of alternative hosts or other reasons (Howard and Fiske 1911).

Future

Worldwide, gypsy moth outbreaks exhibit spatial synchrony and periodicity; outbreaks recur every 5–10 yr (Johnson et al. 2005, 2006). Outbreaking populations usually collapse following epizootics by one of two gypsy moth pathogens, the virus LdMNPV, which is omnipresent in worldwide gypsy moth populations, and the fungus E. maimaiga, whose abundance is influenced by climate and which is thus not usually present in xeric environments such as in Central Asia. In Kazakhstan, gypsy moth outbreaks have been observed to recur every 8–10 yr in most forested areas; however, gypsy moth outbreaks in the walnut–fruit forests of Kyrgyzstan have occurred almost continuously for the past 30–35 yr (Gininenko 1986, Orozumbekov et al. 2003). Although one of the main regulators of high–density gypsy moth populations, E. maimaiga, is not found in the walnut–fruit forests, this does not seem to explain the lack of effective high–density gypsy moth population regulation. In North America, outbreaks have historically collapsed, even during the early period of its invasion and even in the absence of E. maimaiga, which was not present in North America until at least 1989 (Hajek 1999). Indeed, we have observed many LdMNPV epizootics in Kyrgyzstan, but the cycling of populations does not appear to be geographically synchronized and consequently outbreak populations are present in the region virtually every year. Although the reasons for this lack of synchrony and consequent sustained gypsy moth outbreaks in walnut–fruit forests remains a mystery, it is clear that additional studies of the biology and ecology of gypsy moth in Central Asia are needed to sustain this valuable Central Asian resource.

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References Cited


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