Figure 1. The Ramanagara cocoon market, one of the largest cocoon markets in Asia. It is situated 40 km from Bangalore towards Mysore. In this market an average of 40,000 to 50,000 kg of cocoons are sold each day.

Metapopulation biology of the Indian uzifly, *Exorista sorbillans* (Wiedemann) (Diptera: Tachinidae)

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Introduction

The study of metapopulation biology is an important aspect of monitoring insect populations in agricultural as well as forest ecosystems. It concerns the study of spatially separated populations of a species that are sometimes connected by a process of dispersion or migration (Hanski 1998). Here we briefly discuss the metapopulation biology of the Indian uzifly, *Exorista sorbillans* (Wiedemann), an endoparasitoid of the silkworm *Bombyx mori* (L.), which accounts for significant loss to the silk growing farmers around the world (Sengupta *et al*. 1990).

Before 1980, uziflies were found only in northeastern India in places like West Bengal and other neighboring areas. These flies entered South India around 1980 through anthropogenic means by the unauthorized transport of infested silkworm seed cocoons from West Bengal to Karnataka. Since that time the fly has spread throughout all of the southern silk producing states. The flight range of the uzifly is around 3 km (Narayanaswany & Devaiah, 1998).

Karnataka is the major silk producing state in India, followed by Andhra Pradesh and Tamil Nadu. Silk is produced throughout the year in these states and comes under uzifly attack year-round. Cocoons are transported about 500 km from the silk-producing places to be sold at the Ramanagara cocoon market, one of the biggest cocoon markets in Asia, which is situated on the Bangalore Mysore highway in Karnataka (Figs. 1–2). Here infested silkworm cocoons arrive at the market along with good cocoons. The maggots emerge from cocoons and crawl here and there searching for suitable places for pupariation (Figs. 3–4). Furthermore, seed cocoons grown near Bangalore are transported to different parts of Karnataka and adjacent areas along with infested cocoons for seed production and thereby contribute to potential anthropogenic means of dispersion of uziflies in South India. This dispersion helps to maintain a stable metapopulation of uziflies in South India.

Figure 2. Inside the cocoon market. Farmers have filled cages with their cocoons and are awaiting a transaction.

Figure 3. Uzifly maggots that fell from infested silkworm cocoons are being collecting by a farmer in the market. After emerging from the cocoons, these maggots search for suitable places for pupariation, such as crevices or sand.

Over the years since 1980, uzifly populations have declined drastically; during the 1980s there were reports that uziflies caused crop losses of about 50%. Crop losses are now estimated at about 8–10% annually. This reduction is largely due to control measures taken by farming communities in South India, which directly affects the dynamics of uziflies and their abundance.

Spatial structuring of population cycles across generations, seasons and years has important implications for modeling strategies to combat uziflies and other economically important insect pests of silkworms. Temperature, humidity and rainfall patterns have strong influences on uzifly populations (Narayanaswamy & Devaiah 1998); however, food/host availability is also equally important in forecasting population abundance.

Figure 4. Close-up of maggots that were crawling on the market floor. These will be collected and disposed of. House sparrows will also eat the maggots that emerge from the cocoons in the market.

Factors affecting uzifly population dynamics

There are a number of extrinsic and intrinsic factors that influence uzifly population dynamics. The extrinsic factors include temperature, humidity, rainfall, host availability and altitude. The intrinsic factors include Wolbachia load/density and number of individual uzi maggots that develop per host silkworm.

How *Wolbachia* influences population dynamics of uziflies

Wolbachia can influence uzifly populations by inducing fluctuations in population cycles. *Wolbachia* is a reproductive manipulator of arthropods and has various strategies for transovarial transmission. The uzifly harbors A and B supergroup *Wolbachia* (Prakash & Puttaraju 2007) and these have positive effects that influence oogenesis and increase fecundity by 20% (Puttaraju & Prakash 2009). The fluctuations in fecundity and hatchability has been observed in nature with varying temperatures, humidity and rainfall (Prakash 2006). During summer months between the middle of March and the second week of June the temperature climbs to 32–40°C and this has a negative effect on the growth rate of uziflies. In these months less than 20% egg hatchability was observed in natural populations (Prakash 2006). This could be due to high temperatures affecting differentially the A and B group *Wolbachia*, leading to the expression of different levels of bidirectional cytoplasmic incompatibility (Prakash 2006) or some other physiological mechanism. However, this needs further study for confirmation.

Potentialities of uzifly control

Other important aspects of metapopulation biology involve the study of patterns of the extinction process. In patchy local/subpopulations extinctions are prevented by high levels of migration or dispersion. By understanding the process of migration and local population extinction, we may be able to bring about the eradication of uzifly populations from silkworm rearing environments.

In conclusion, studies on uzifly metapopulation biology are illuminating various aspects of population growth and extinction rates, which will help in managing uziflies that attack the silkworm *Bombyx mori* (Fig. 5).

Figure 5. Female uziflies one day after emergence from their puparia. They search for silkworms and lay one or two eggs on the body of each caterpillar.

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