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Distribution and Ecology of Malaria Vectors in India: A review

Dr. Seema Verma

Department of Zoology, MSJ, Government College, Bharatpur, Rajasthan

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ABSTRACT

Malaria is the most common infectious disease and a public health problem in India. India has several species of malaria vectors. Anopheles culicifacies, Anopheles fluviatilis, Anopheles baimaii, Anopheles sundaicus and Anopheles stephensi are major and primary malaria vectors and Anopheles philippinensis, Anopheles varuna, Anopheles nivipes and Anopheles annularis are also identified as secondary malaria vectors from various geographic regions of India. Out of those, Anopheles culicifacies and Anopheles fluviatilis are major vectors of malaria in India. Anopheles culicifacies generally occurs in hilly areas, while Anopheles fluviatilis occurs in plain areas of the country. Anopheles culicifacies breeds in pools, river beds and rainwater storage areas, as well as in swamps, rice fields, burrow pits and irrigation canals. Anopheles fluviatilis breeds in river margins, irrigation canals, shallow wells, seepage water streams, and rice-field foothill habitat. Anopheles stephensi is an urban mosquito vector of malaria in India. It's preferred to breed in domestic containments, in construction sites, in overhead and unground cemented tanks, and in chambers of coolers.

Introduction

Malaria is the most common infectious disease and public health problem in India. India has various malarial vectors species due to variation in ecological and climatic conditions favors growth of mosquitoes (Sharma, 1998). Only India accounts for 80% of malaria cases in Southeast Asia, where the risk of malaria transmission is high. In 2011, India reported 1.3 million confirmed malaria cases and 753 deaths reported due to malaria, but estimated infection and death rates are 10 to 20 times higher (Dhingra *et al.*, 2010; NVBCP, 2012). In recent years, malaria has been responsible for thousands of deaths of humans in the tropical and subtropical regions of the world, especially in the Indian subcontinent, Southeast Asia, Africa and South America. Two plasmodium strains occur in India, namely *Plasmodium falciparum* and *Plasmodium vivax*. At present, *Plasmodium vivax* is more frequently detected in new malaria cases as compared to *Plasmodium falciparum*. It may be influenced due to the distribution and dissemination of chloroquine resistance and established multidrug-resistant properties (Shah *et al.*, 2011). In this review study, I discuss the distribution, ecology and diversity of malaria vectors in India and the life cycle of *Plasmodium*.

1. Distribution, Ecology and diversity of Malaria vectors in India

Anopheles culicifacies, *Anopheles fluviatilis*, *Anopheles baimaii*, *Anopheles sundaicus* and *Anopheles stephensi* are major and primary malarial vectors in different geographical regions of India. *Anopheles philippinensis*, *Anopheles varuna*, *Anopheles nivipes* and *Anopheles annularis* are also identified as secondary malarial vectors from various region of India. These species increase the anopheline vector fauna in India (Subbarao, 1998; Dash *et al.*, 2007; WHO-SEARO, 2007). These *Anopheles* species have distinct biological and ecological characteristics, as well as habitat preferences and exhibit distinct distribution patterns across the country. *Anopheles culicifacies* and *Anopheles fluviatilis* are major vectors contributing to malaria transmission in India. *Anopheles culicifacies* is responsible for 60–70% of malaria transmission in India. *Anopheles fluviatilis* is the major mosquito vector in the hilly regions of the country, while *Anopheles culicifacies* performs as a secondary vector in the plains and forest regions. *Anopheles culicifacies* is also responsible for transmitting malaria in plain areas of the country. Several types of studies have been carried out in India on the resting and biting behaviour of *Anopheles culicifacies* and *Anopheles fluviatilis* (Rao, 1984; Singh *et al.*, 1999; Nanda *et al.*, 2000). *Anopheles minimus* breeds in the streams of the foothills of northeast India, while *Anopheles dirus s.l.* is distributed in the north-eastern states of India. *Anopheles sundaicus* is found in brackish water habitat on the Andaman and Nicobar Islands. *Anopheles stephensi* is also known as an urban malaria vector in India (Subbarao, 1998). *Anopheles culicifacies* is found in high altitudinal ranges of Himalayan regions (up to 3000 meter elevations) and Kashmir regions, but not in Lakshadweep, Andaman and Nicobar islands (Nagpal and Sharma, 1995; Subbarao, 1998; Raghavendra *et al.*, 2011). The biology and genetics of *Anopheles culicifacies* have been extensively studied in India, and at present it is characterized as a species complex with five designated species, namely A,B,C,D and E (Sharma, 2006; Barik *et al.*, 2009). *Anopheles culicifacies* breeds in pools, river beds and rainwater storage areas, as well as steams, rice fields, burrow pits and irrigation canals (Rao, 1984; Nagpal and Sharma, 1995).

Anopheles fluviatilis s.l. is found in the country's hills and foothills and it accounts for nearly 15% of all malaria

cases reported in India each year (Sharma, 1998). Based on the cytotaxonomic investigation for fixed chromosomal readable in the polytene chromosome arm, *Anopheles fluviatilis s.l.* is recognized as a three-sibling species (S, T and U) and formed V (Rao, 1984; Subbarao *et al.*, 1994; Nagpal and Sharma, 1995; Subbarao, 1998; Raghavendra *et al.*, 2011). Because of diagnostic inversion polymorphism, distinguishing S and T siblings is difficult, but biological characteristics, features and regional distribution can help (Rao, 1984; Subbarao *et al.*, 1994; Nagpal and Sharma, 1995; Subbarao, 1998; Raghavendra *et al.*, 2011).

The S sibling of *Anopheles fluviatilis s.l.* is responsible for hyper-endemic malaria transmission in certain regions of eastern India, including Odisha state (Nanda *et al.*, 1996). Sibling S prefers to rest in indoor human dwellings, while Sibling T prefers cattle shed for resting (Gunasekaran *et al.*, 1989; Sharma *et al.*, 1995; Nanda *et al.*, 2000). Siblings show similar characteristics but have a limited distribution, especially in northern India (Gunasekaran *et al.*, 1989; Sharma *et al.*, 1995; Nanda *et al.*, 2000). *Anopheles fluviatilis* breeds in river margins, irrigation canals, shallow wells, seepage water streams and rice-field foothill habitat (Rao, 1984; Sahu *et al.*, 1990; Nagpal and Sharma, 1995). *Anopheles fluviatilis* is most active in the evening, between 20:00 and 24:00, when it bites the most. These times vary by season and location. The breeding and resting habitat preferences of *Anopheles fluviatilis* species S and *Anopheles minimus* were nearly identical (Dev and Phookan, 1998).

Anopheles minimus is distributed in the eastern and north-eastern regions and the sub-Himalayan foothills region of India (Garros *et al.*, 2006). *Anopheles minimus* was widely distributed in Assam and the Bengal region prior to the DDT era (1940s) (Viswanathan *et al.*, 1941; Muirhed and Thomas, 1941; Senior White *et al.*, 1945; Misra and Dhar, 1955; Mishra, 1956; Gilroy, 1958), but its distribution ranges have now become restricted and it has disappeared from the Terai region of Uttarakhand, eastern Odisha and the north-east region of Nepal. *Anopheles dirus s.l.* and *Anopheles philippinensis* cause malaria in the north-eastern region of India (Rajagopal, 1976). *Anopheles dirus s.l.* has seven sibling species and occurs in different regions of the world. These are *Anopheles dirus.s.* (species A), *Anopheles cracens* (species B), *Anopheles scanloni* (species C), *Anopheles baimaii* (species D), *Anopheles elegans* (species E), *Anopheles nemophilous* (species F), *Anopheles takasagoensis* and *Anopheles aff. takasagoensis*. All seven species have distinct morphological features and distributional ranges in Southeast Asia (Manguin *et al.*, 2008; Dev, 1994), while eight species were reported from northern Vietnam; they are morphologically similar but phenotypically distinct from both *Anopheles dirus* and *Anopheles takasagoensis* (Takano *et al.*, 2010).

Anopheles sundaicus s.l. is a major malaria vector found throughout the oriental region. At present, it has a complex of four species: *Anopheles sundaicus s.s.*, *Anopheles epiroticus* Linton & Harbach (formerly species A), *Anopheles sundaicus* species D and *Anopheles sundaicus* species E (Subbarao, 1998; Nanda *et al.*, 2004; Dusfour *et al.*, 2007; Manguin *et al.*, 2008; Sinka *et al.*, 2011 and 2012). It has disappeared from the eastern coastal belt of west Bengal and Orissa (Singh *et al.*, 1985) and is widely distributed in the Andaman and Nicobar Islands population, where it is considered a cytotype species D (Das *et al.*, 1998; Nagpal *et al.*, 2003; Nanda *et al.*, 2004).

Anopheles stephensi is an urban mosquito vector of malaria (Nagpal and Sharma, 1995). It is not considered a species complex, but it is comprised of three ecological variants, namely; the type form, the intermediate form and Variety mysorensis. These ecological forms are characterized by egg morphometric variations (Sweet and Rao, 1938; Subbarao *et al.*, 1987; Sharma *et al.*, 1993).

The type form is a significant malaria vector in urban habitat, while the variety mysorensis is mostly zoophilic and does not contribute to malaria transmission (Sharma *et al.*, 1993; Chakraborty *et al.*, 1998; Ghosh *et al.*, 2008). The intermediate form of *Anopheles stephensi* generally occurs in periurban and rural areas and its transmission ecology was not properly studied. The ecological variations of all three forms are further proved by variation in the Y-chromosome (Saguna, 1992), spiracular index and the frequencies of inversion of polymorphisms in rural and urban population ranges of their distribution (Saguna, 1981; Mahmood and Sakai, 1984). The main transmission period of *Anopheles stephensi* occurs in the rainy season, especially from June to August. In urban areas, it is breeding in domestic containments, construction sites, over headed and unground cemented tanks and chambers of coolers (Sharma *et al.*, 1993; Sumodan *et al.*, 2004).

2. Life Cycle and Incubation of *Plasmodium* Species

When a *Plasmodium*-containing anopheline mosquito bites a human and consumes a blood meal, sporozoites enter the bloodstream. Within hours of entering the bloodstream, sporozoites reach hepatocytes cells and begin the next developmental stage, merozoites. The dormant forms of *Plasmodium vivax* and *Plasmodium ovale* are also known as hypnozoites, while *Plasmodium falciparum* does not produce any dormant forms or hypnozoites.

Merozoites can invade erythrocytes and develop into trophozoites after leaving the liver. It is a ring-shaped, uni-nucleated and vacuolated stage (Garcia, 2001; Trampuz *et al.*, 2003). When trophozoites gain the capacity to divide, they are known as schizonts. Schizonts contained several merozoites. After this event, infected erythrocytes were lysed and several merozoites invaded the erythrocytes and induced a new schizogony cycle in the new erythrocytes cell (Gracia, 2001; Trampuz *et al.*, 2003).

In *Plasmodium falcipaurm*, each cycle can last up to 48 hours, but the infection rate is 20 times higher in non-immunized humans. After the various cycles of merozoites, it is further developed into the gametocyte stage. The sexual phase of malaria is represented by gametocyte stages, which

cause no symptoms in humans but are infectious to mosquitos (Gracia, 2001; Trampuz *et al.*, 2003).The pre-patent period of *Plasmodium falciparum* ranges up to 10 days and the median incubation period is 11 days. The incubation period may be significantly influenced by the level of immunity in the person and the time interval between previous exposure and current exposure, as well as by prior treatment given at the time of previous exposure (Taylor and Strickland, 2000; Trampuz *et al.*, 2003).

The non-Falciparum form has a longer incubation period than the Falciparum form. *Plasmodium vivax* and *Plasmodium ovale* can survive in the human body for months or years due to the presence of hypnozoites in the liver (Taylor and Strickland, 2000). The highest 30-year incubation periods were reported for *Plasmodium vivax* (White, 2003). The primary symptoms of malaria are due to schizont rupture and destruction of erythrocytes. After the erythrocytes, malaria symptoms resemble with common viral infection. Malaria patient shows fever, headache, chills and diaphoresis sympotms (Genton and Acremont, 2001).

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