ANOPHELES FLUVIATILIS SPECIES COMPLEX: DISTRIBUTION AND ROLE IN MALARIA TRANSMISSION

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ABSTRACT

Anopheles fluviatilis James is a major malaria vector in India, Pakistan, Nepal and Iran. It belongs to subgenus Celia and Minimus group of series Myzomia. It is a complex of four isomorphic sibling species S, T, U and V. They are distinguished on the basis of fixed paracentric chromosomal inversions present on polytene chromosome arm 2. Members of this complex differ in their biological characteristics, distribution and role in malaria transmission. This review focuses on available techniques for sibling species identification, their geographical distribution, biological characteristics and role in malaria transmission. Understanding of the bionomics and vectorial efficiency of all the four sibling species would help in adopting the appropriate vector control strategies.

KEYWORDS: Anopheles fluviatilis, Malaria, Species complex, Biological characteristics, Distribution

INTRODUCTION

Mosquito vectors are responsible for transmitting numerous deadly diseases such as malaria, dengue, Chikungunya, Japanese encephalitis and lymphatic filariasis. Annually malaria causes 6,27000 deaths worldwide and more than 15000 in India (WHO, 2013). Malaria is caused by four different plasmodia species and transmitted by approximately 60 species of anopheline mosquitoes (Oaks et al., 1991). Culicifacies and Fluviatilis Complexes are widely studied vector systems in India, which together responsible for most of the malaria cases. Anopheles fluviatilis James (Diptera: culicidae) is an important malaria vector in India, Pakistan and Nepal (Nagpal et al., 1995, Rao TR, 1984). Recent development in vector biology have revealed that the vectorial capacity and competence of each sibling species is different including their behavioural characteristics, breeding habitats, host specificity and susceptibility to malaria parasites and insecticides (Ghosh et al., 2008, Barik et al., 2009, Tripathy et al., 2010). This review illustrates the types of sibling species, their identification, bionomics, vectorial capacity and their role in malaria transmission.
1. Sibling species and their identification

Identification of the cryptic species is of paramount importance in disease control program due to contrasting differences in their vectorial capacity, feeding preferences and resting behaviour. *Anopheles fluviatilis* s.l. exists as four morphologically indistinguishable sibling or cryptic species, species S, T, U and V (Subbarao et al., 1994, Nanda et al., 2013). Rao (1984) first indicated the presence of two biological forms of this species differ in population densities, feeding preferences and plasmodium infection rates. Later, subbarao et al (1994) revealed the presence of three sibling species within *An. fluviatilis* in India, designated as species S, T and U which are distinguished by fixed paracentric chromosomal inversions in polytene chromosome arm 2 (Table 1). *An. fluviatilis* referred as species X and Y based on differences in the nucleotide sequences of ITS2 region of ribosomal DNA (rDNA) in Odisha states in east-central India (Manomani et al., 2001). Subsequent comparison with cytotaxonomy revealed that 94% of species X were species S and 90% of species Y were species T (Manomani et al., 2003). Observation of ITS2 sequence in Iranian *An. fluviatilis* mosquitoes found that they were identical to that of species T (as species Y) in India (Naddaf Sczfouli et al., 2002, 2003). An allele-specific PCR assay was developed for identification of *An. fluviatilis* S, T and U based on differences in nucleotide sequence within the D3 domain of 28S rDNA (Singh et al., 2004). Recently cytogenetic and molecular investigations of *An. fluviatilis* population in district Haridwar in northern India have established the existence of a new cryptic species in the fluviatilis complex which has been provisionally designated as species V (Nanda et al., 2013). Till now exact distribution pattern, biological characteristics and role in malaria transmission of species V is not known.

In recent years some authors considered *An. fluviatilis* Species S, an important malaria vector in India as a synonym of *An. minimus* C (Harbach 2004, Garros et al., 2005, Chen et al., 2006). These reports are based on a comparison of 335 base pair nucleotide sequence of the D3 domain of 28S (28S- D3) ribosomal DNA (rDNA) of *An. fluviatilis* species S with that of *An. minimus* species C and similarity in biological characteristics. Later sequencing of D2-D3 domain of 28S rDNA, ITS2 and cytochrome oxidase II revealed that *An. fluviatilis* S and *An. minimus* C are infact independent species (Singh OP., 2006).

2. Distribution

The distribution of *An. fluviatilis* s.l. extends from Yemen to Taiwan (Knight and Stone, 1977). It is distributed in eastern Asia (Pakistan, Afghanistan, India, Nepal, and Bangladesh)
and in parts of western Asia (Iran, Iraq, eastern and southern Saudi Arabia, Oman, Bahrain, and Russia (Rao, 1984). Earlier reports of its presence in Thailand, east of Myanmar and southern China have been regarded as misidentification of *Anopheles minimus* due to overlapping morphological characters (Harrison 1980, Chen et al., 2002, Singh et al., 2010).

In India *An. fluviatilis* T is the most widely distributed species of this complex. It is recorded from the states of Gujarat, Madhya Pradesh, Odisha, Rajasthan, Himachal Pradesh and Uttar Pradesh in India (Subbarao et al., 1994, Nanda et al., 1996, Singh et al., 2004) (Figure 1). Species S is mainly found in Odisha State in India (Manonmani et al. 2001). Species U is recorded from Uttar Pradesh state (Subbarao et al., 1994, Nanda et al., 1996, Singh et al., 2004 and Chen et al., 2006) (Figure 1).

In Iran *An. fluviatilis* distributed on the southern slopes of the Zagros chain, from southwest of Kermanshah to Baluchestan in the south-eastern part of the country. It is considered a secondary vector of malaria in Fars, Hormozgan and Khuzestan provinces, and is found at altitudes ranging from 50 meters to 1100 meters (Eshghi et al., 1976). In Iran species T is found in Fars, Hormozgan, Kerman, Sistan and Baluchestan provinces (Naddaf Dezfooli et al., 2002) and species S is recorded only from Hormozgan province (Djadid et al., Unpublished). *An. fluviatilis* species U has been reported first time in south-eastern Iran by Mehravaran et al (2011).

![Figure 1. Map showing the distribution of *An. fluviatilis* sibling species in India](source: The map is courtesy of Dr. Nutan Nanda, NIMR, Delhi)
3. Biological Characteristics

The sibling species of Fluviatilis complex have been reported to vary in their biological characteristics (Subbarao, 1998). Species S is distinctly different in several biological characters from species T and U as seen in Table 1. Species S was found either alone or in sympatric association with species T, and species U was more frequently found with species T.

3.1 Occurrence and Habitat

An. fluviatilis species S mainly found in hilly and forested area while species T and U is found in foothills and plains (Nanda et al., 1996) (Table 1). Slow-runing streams, irrigation channels and subsoil seepage water with grassy margins are the major breeding habitats for An. fluviatilis in Shivalik range of the Himalayas in Haridwar and Dehradun districts of Uttaranchal state (Sharma et al., 1995). In Malkangiri and Koraput districts in Odisha, An. fluviatilis s.l. breeds in terraced paddy fields, streams and stream channels (Sahu et al., 1990). In Iran, An. fluviatilis breeds in fresh; slow flowing or stagnant waters, vast marshes, riverbanks, pits in the beds of stony and sandy rivers and rainfall pits (Eshghi et al., 1976).

3.2 Density and Resting behaviour

An. fluviatilis rests both indoors and outdoors. Man-hour density (MHD) of species S is ranged from 1 to 40 and preferred adult habitat is human dwellings. In contrast species T and U has MHD up to 200 and mainly found in cattle sheds (Nanda et al., 1996) (Table 1). In Keonjhar district, Odisha An. fluviatilis s.l. density was higher in human dwellings than cattle sheds. Density of An. fluviatilis s.l. in human dwellings peaked during rainy and winter streams and walls were the most preferred site (Sahu et al., 2011). Shukla et al (1998) noticed that An. fluviatilis species T and U were found resting indoors predominantly in cattle sheds in Nainital districts, Uttar Pradesh. In Haridwar and Dehradun districts of Uttarakhand state, An. fluviatilis s.l. was found throughout the year with high densities in October/ November and low densities in May to August (Sharma et al., 1995). A preliminary observation made on the biological characteristics of species V revealed that it rests predominantly in human and mixed dwellings and has an anthropophagic index of about 4%.
3.3 Feeding preference

Species S has been recognized as a highly efficient malaria vector and is highly anthropophagic whereas species T and U are primarily zoophagic and considered as poor vectors (Nanda et al., 1996, Sharma et al., 1995, Shukla et al., 1998) (Table 1).

Table 1. Biological differences and diagnostic characters of *An. fluviatilis* sibling species

<table>
<thead>
<tr>
<th>Sibling Species*</th>
<th>Inversions genotypes on chromosome arm 2</th>
<th>Densities (MHD)</th>
<th>Feeding preferences</th>
<th>Preferred adult habitats</th>
<th>Observed Ecotypes</th>
<th>Observed in Epidemiological areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>+q1+r1</td>
<td>Low to moderate (1-40)</td>
<td>Anthropophagic</td>
<td>Human dwellings</td>
<td>Hilly forest &amp; foothills</td>
<td>Hyperendemic</td>
</tr>
<tr>
<td>T</td>
<td>q1+rl</td>
<td>High (up to 200)</td>
<td>Almost totally zoophagic</td>
<td>Cattleshed</td>
<td>Foothills &amp; plains</td>
<td>Hypo-mesoendemic</td>
</tr>
<tr>
<td>U</td>
<td>+q1r1</td>
<td>-do-</td>
<td>-do-</td>
<td>-do-</td>
<td>-do-</td>
<td>-do-</td>
</tr>
</tbody>
</table>

*Source Reference No. 24, **Distribution, bionomics and biology of new sibling form ‘V’ is being investigated

4. Role in malaria transmission

4.1 Susceptibility to sporogony in laboratory feeding experiments

Laboratory feeding experiments of different members of Fluviatilis Complex revealed that all three species S, T and U are susceptible to malaria sporogony. Adak et al (2005) compared the susceptibility of *An. fluviatilis* species T, with two well established malaria vectors, *An. stephensi* and *An. sundaicus* in laboratory feeding experiments by feeding them on *Plasmodium vivax* infected blood. Examination of gut of mosquitoes revealed that all the three species had high oocyst and sporozoite rates and there were no significant differences in these rates among all the three species. Similar results were found with species U in laboratory feeding experiment. These results suggested that *An. fluviatilis* species T and U in India are genetically susceptible to plasmodium infection. This is probably because of its zoophagic nature making it a non vector, but may act as vector where man: cattle ratio is high. Moreover, recently Mehrunissa et al (2013) compared the susceptibility of species T and U to rodent malaria parasite *Plasmodium vinckei petteri* in a laboratory experiment. Results showed that both these species are able to support the malaria sporogony in laboratory.
4.2 Anthropophillic index and sporozoite rate

Anopheles fluviatilis species S is mainly anthropophilic while species T and U are primarily zoophilic. In the mining areas of Sundergarh district (Odisha) sporozoite rate based on dissections was 1.8%. In another study in Uttarakhand, the sporozoite rates were 1.4%, 0%, and 62% during the months of September, October and November 1982 respectively (Choudhury et al., 1983). In a study carried out in eight different malaria endemic districts of Odisha, it was found that species S was predominantly present and its anthropophilic index and sporozoite rate values ranged from 60.7-90.4% and 1.2-2.32% respectively (Tripathy et al., 2010). It was also suggested that species S of Fluviatilis Complex is the principal vector of malaria in central forest areas of district Bastar (Chhattisgarh), India with sporozoite rate was 2.31 (Nanda et al., 2012). A recent study carried out in Jabalpur (Madhya Pradesh), India suggested that An. fluviatilis species T is a major malaria vector in this region. The overall sporozoite rate of An. fluviatilis was 0.90% (0.45% for P. falciparum and 0.45% for P. vivax) in this region (Singh et al., 2015).

4.3 Vectorial capacity

Vectorial capacity expresses the potential for malaria transmission. The vectorial capacity estimates in Keonjhar (Odisha), India for An. fluviatilis ranged between 0.04 to 1.28 for P. falciparum and between 0.2 to 1.54 for P. vivax. It has higher values in summer months and lower values in winter season (Gunasekaran et al., 2014). Recently An. fluviatilis species T was found as vector in forest villages of Balaghat district (Madhya Pradesh), India (Singh et al., 2013). A Study carried out in Iran also suggested that Anopheles fluviatilis is a main malaria vector in Southern part of Iran. Vectorial capacity of Anopheles fluviatilis for Plasmodium vivax was 2.5, 0.2, 0.4 in summer, autumn and spring but 1.7, 0.07, 0.24 for P. falciparum, respectively in this area (Edalat et al., 2005).

5. Conclusion

The success of any vector control programme relies on knowledge of vector species and their bionomics. There are growing evidences that the members of species complexes differ in their biological characteristics such as vectorial capacity, host-preference, resting behaviour and response to insecticides. Therefore, understanding the distribution, bionomics, and vectorial efficiency is essential for planning the suitable vector control strategies.
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References


