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Prevalence of vector mosquitoes of major mosquito borne diseases in areas of Indira Sagar Projection Madhya Pradesh, India

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Abstract
Indira Sagar Project (ISP) is one of the highly ambitious projects designed for generating electricity and providing irrigation to many parts of Madhya Pradesh. A study to assess prevalence of major mosquito vectors was carried out since Jan 2013- Dec 2014 in ISP areas mentioned as Submergence (SUB), main canal mentioned as Command (CMD), and 2 Resettlement and Rehabilitation colonies mentioned as RR colonies. Malaria vector An. culicifacies was found to be dominating species in all the study areas, *An. fluviatilis* was found both in SUB and CMD areas and *An. stephensi* was found in RR Colonies. *Cx. quinquefasciatus* was observed as vector of LF in all areas. As a vector of JE, *Cx. vishnui* was observed from SUB and *Ae. aegypti* as vector of dengue and chikungunya was observed from all SUB, CMD and RR colonies. Larval densities showed significant differences in SUB; $t(12) = 2.53$, $p=.016$ (SUB), for CMD; $t(12)= 3.97$, $p=.001$, and for RR; $t(12)= 2.17$, $p=.041$. Regular surveillance of disease vectors in dam specific components will help to formulate new strategies of vector control. This study reports for the first time in India a comparative study in areas affected with both, reservoir of a dam and irrigation channel.

Keywords: water development project, canal, An. culicifacies, *An. fluviatilis, Ae. aegypti, Cx. quinquefasciatus, Wuchereria bancrofti.*

1. Introduction

With ever expanding population throughout world, environmental modifications to satiate the need of growing population have become inevitable. As a result, new interactions between humans and environment have altered the epidemiological patterns of many vector-borne diseases [1]. Irrigation schemes and dams have extensively grown in past decades to cover the increasing food and energetic demands mainly in Africa, Asia and the Pacific and the Americas [2], it is estimated that at least 40,000 large dams (defined as impoundments more than 15 meters high or storing more than 3 million m of water) and 800,000 small dams have been built worldwide [3]. A total of 18.3 million people within 2 km of the shoreline of a dam and other 851.3 million people near irrigation channels are estimated to inhabit areas in close proximity to water development projects (WDP) creating ample opportunities for host-vector interaction [3]. There is growing evidence that demographic movements in need of food and shelter coupled with environmental alterations favour proliferation of vector-borne diseases namely malaria, lymphatic filariasis, Japanese B encephalitis and onchocerciasis [4]. When huge projects are built a lot of population moves from highly endemic areas to the previously unexposed areas. Construction of new (WDP) also accompanies a lot of changes in temperature, humidity, acquired immunity level to vector borne diseases depending on previous exposure to the causative organism and several other factors. All these factors play a major role in determining new foci for transmission of vector borne diseases [5]. Amongst these vector borne diseases, mosquito borne diseases are widely associated to a WDP and many water development projects have witnessed an increased malaria transmission in affected areas [6-11]. Like other countries, India has also witnessed manifold increase in both Anopheline density and malaria transmission related to Water Development Projects [6-12]. In a huge country like India malaria endemicity gets complicated with diverse ecology and multiple disease vectors [13]. Any introduction of a water development project may further add on to the already existing burden of vector borne diseases eventually mosquito borne-diseases due to influx of labourers from endemic areas. Movement from one construction site to other, offers parasite load which may result in upsurge of malaria cases [14]. There are six efficient vectors of malaria, of which three are common in central India, namely *An. culicifacies*, *An. stephensi* and *An. Fluviatilis* [15, 16]. *An. culicifacies* is the major malaria vector in rural India which contributes to the transmission of about 65% of the total malaria cases in India [17]. It has also been reported that this species is responsible for unstable malaria with epidemic potential in many areas [18]. Lymphatic filariasis is known to be caused mainly by *Wuchereria bancrofti* (>99%) and *Cx. quinquefasciatus* mosquito is widely known to transmit it. The principal vector for transmitting Japanese Encephalitis virus is known as *Cx. vishnui* group of mosquitoes [19]. Dengue and chikungunya, the most detrimental arboviral diseases are known to be transmitted by *Ae. Aegypti* [20]. Despite their wide spread as potential dominant vectors, very limited studies on vector prevalence in relation to a WDP have been reported in India so far. Current study hence focuses on vector prevalence in Indira Sagar Dam components namely submergence areas (SUB), command areas (CMD) and Resettlement and Rehabilitation colonies (RR).

2. Materials and Methods

2.1. Study Sites

Blue prints of areas affected with ISP were collected from various engineering departments of Khandwa, Khargone and Indore to work out the areas of study. Villages falling into the periphery of 3 kms of dam impoundments of Indira Sagar Dam and canal areas were selected based on flight range of mosquitoes i.e. approximately 3 kms [10]. Six villages were selected from SUB, five from CMD areas, and two RR colonies of East and West Nimar districts of MP state (earlier known as Khandwa and Khargone districts) as shown in Fig-1. The six villages selected from SUB areas were- Reechi (N 22^{0}14’642" E 076^{0}25’040"), Bedhani (N-22^{0}14’162" E-076^{0}25’678"), Piplani (N-22^{0}13’424" E-076^{0}26’305"), Chiktikhal (N-22^{0}10’687" E-076^{0}27’339"), Chandel (N-22^{0}11’840" E-076^{0}27’300"), and Jamkota (N-22^{0}08’311" E-076^{0}29’590"). From CMD areas, the selected villages were - Guradiya (N-22^{0}04’964" E-075^{0}59'316"), Piprikheda (N-22^{0}02’996" E-075^{0}58'026"), Atarsumbha (N 22^{0}03’839" E 75^{0}59'146"), Mokhangaon (N 22^{0}05’994’’ E 076^{0}00’665’’), Birali (N 22^{0}05’587’’ E 076^{0}01’735’’) were selected and from RR colonies namely Bedhani (N 22^{0} 14’161’’ E 76^{0}25’123’’) and Anjaniya (N 22^{0} 12’018’’ E 76^{0}26’515’’) were selected (Fig-1). Housing pattern was also observed in all the three components. The houses in submergence had mixed pattern i.e. some were made of mud and others of cement, houses in command were majorly made of mud and had thatched roofs and houses in RR colonies were majorly made of cement and had asbestos roofing. These villages were not sprayed since 2000 with indoor residual insecticide. The duration of this study was from Jan 2013 to Dec 2014.

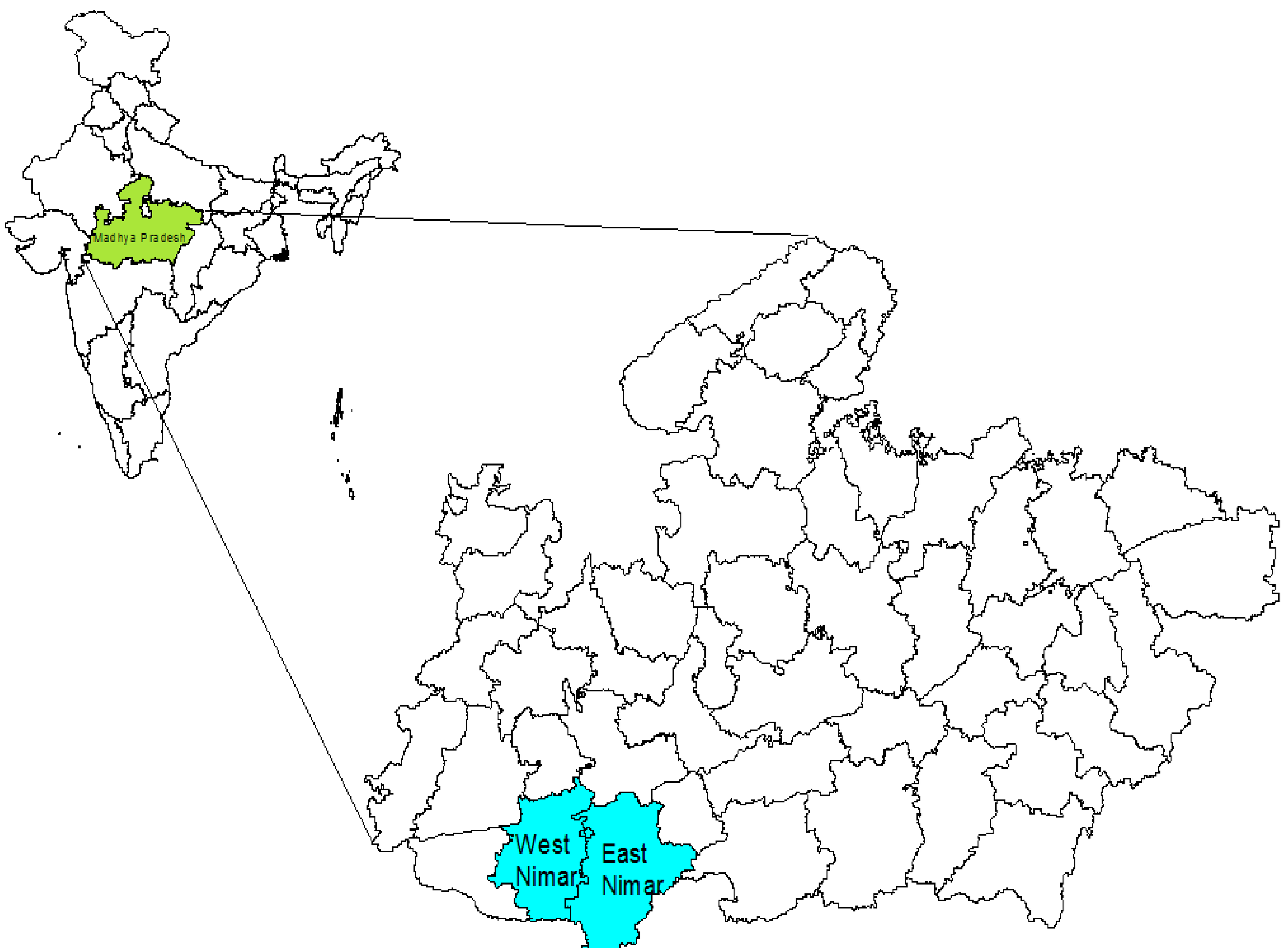

Fig 1: ISP Study Sites Selected For Study Are Shown In Cyan. East Nimar and West Nimar Formerly Known As Khandwa and Khargone Respectively In Madhya Pradesh, India

2.2. Entomological data collection
Data on vector prevalence was collected by two methods total catch and light trap and larval breeding was also carried out by using standard WHO methodology.

(i) Space Spray Collection (total catch)

For space spray collection atleast 4 houses were selected in all the villages after searching mosquitoes in each village with help of a torch and suction tube. Rooms of standard size dimension which is approximately 4x5 m or 10x12 m was selected and all the outlets were closed. The whole area inside was covered with white bed-sheets and an aerosol insecticide under brand name Hit [composition: d-trans Allethrin a.i. 0.25%w/w + Synergist (PBO) 0.50 % w/w + Perfume 0.20 % w/w + deodorized kerosene 39.05 % w/w + Propellant gas (LPG) 60.0 % w/w = Total 100 % w/w] was sprayed in the Room and left for 10-15 minutes. After that, all bed-sheets were taken out carefully and the mosquito species were collected on a petri-dish in wet cotton. They were also analyzed for different gravid conditions and were segregated as gravid, semi-gravid, half-fed and fully-fed.

(ii) Light trap collection

To determine the composition of possibly exophilic vectors, whole night mosquito catches using light trap was done. Efforts were made to install a light trap at a fixed place to rule out any place bias except during heavy rain. In a village only one light trap was used each night. Mosquitoes collected overnight were kept separately and identified using the key of Nagpal *et al.* [21] and Christopher [22].

(iii) Larval breeding habitat

Mosquito breeding survey was carried out by the standard WHO methods using bowls and dipper from water bodies and domestic and peri-domestic breeding containers. All water bodies created due to canal and dam seepage namely ditches, pools and pits etc, man-made holes at construction sites, unused curing tanks, pipes, drums, bufflow wallows, hoof prints, margins of reservoir, tree holes and domestic containers were checked for larval breeding. The shallow water bodies were checked using a white bowl and more than 1 m of depth was checked using dipper with a handle of 1 meter making a 45^0 angle from the surface. At least 10 dips were taken from each water body and number of larvae were pooled and counted. Data was pooled as per three seasons i.e. pre monsoon, monsoon and post monsoon. During the survey, the available peri-domestic and intra-domestic breeding was checked in the villages. For breeding of *Aedes* larvae, peri-domestic containers were checked and percentage positivity in terms of container index was calculated with the following formulae-

$$\text{Percentage Positivity} = \frac{\text{Positive Containers}}{\text{Containers Checked}} \times 100$$

$$\text{Container Index (CI)} = \frac{\text{Positive Containers}}{\text{Containers Inspected}} \times 100$$

3. Data analysis
Data were analysed using statistical software SPSS (version20) (SPSS Inc, USA). For non-categorical data, t test was applied. A significance level of p <.05 was considered for t test conditions.

4. Results
4.1. Total Catch
A total of 72,824 mosquitoes were caught in total catch from all the study sites and only 65,204 were found to be the vector species of *Anopheles* (*An*), *Culex* (*Cx*), and *Aedes* (*Ae*), rest of the mosquitoes found were other species of Anopheline namely *An. annularis, An. subpictus, An. barbirostris* etc. Total vectors caught in SUB were 27024, in CMD were 33620 and in RR were 4560. Villages in SUB had 66% *An. culicifacies* and 1% *An. fluviatilis* as major malaria vectors. As a vector of filaria, *Cx. quinquefasciatus* (33%) and vector of JE *Cx. vishnui* (1%) was found in total catch. Vector of dengue and chikungunya *Ae. aegypti* (1%) was also found in SUB areas. In CMD areas 79% of the observed vector species for malaria were *An. culicifacies,* and6% was *An. fluviatilis*. As a vector of filaria, 14% *Cx. quinquefasciatus* was found and 1% *Ae. aegypti* as dengue vector was also found in these areas. In RR colonies 45% *An. culicifacies*and14% *An. stephensi* as malaria vectors, 32% *Cx. quinquefasciatus* as filarial vector and 9% *Ae. aegypti* as dengue vector was found (Fig-2, 3 and 4).

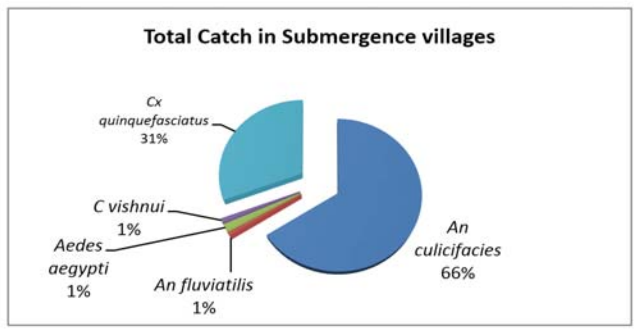

Fig 2: Percentage Proportion of Vector Mosquitoes Observed In Total Catch in Submergence Areas

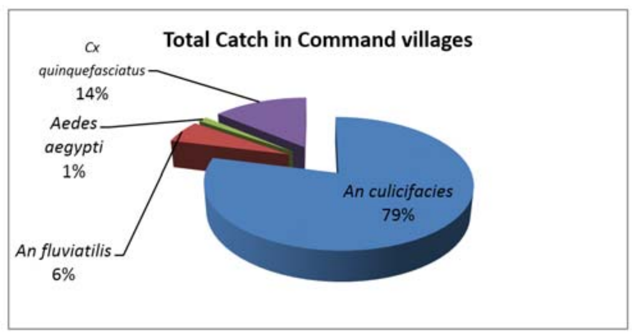

Fig 3: Percentage Proportion of Vector Mosquitoes Observed In Total Catch in Command Areas

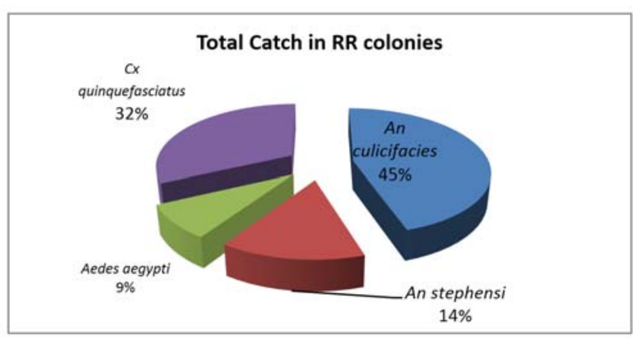

Fig 4: Percentage Proportion of Vector Mosquitoes Observed In Total Catch in RR Colonies

4.2. Light Trap

In light trap catches 540 specimens of anopheline from SUB (64 nights), 1644 from CMD (72 nights) and 320 from RR (64 nights) colonies were recorded. 189 specimens of Culicine from SUB, 128 from CMD and 76 from RR colonies were recorded (Fig 5, 6, 7). Of the 200 light trap catches, 88 were located indoors (28 each in SUB and RR and 32 in CMD) and 112 were outdoors (34 each in SUB and RR and 44 in CMD). In SUB and RR per night per trap catches of *An. culicifacies* were more in indoor while in CMD it was more outdoors. In SUB areas, *An. culicifacies* (32%) was the predominant species followed by *An. subpictus* (26%), *An. fluviatilis* (7%) and other anopheline (22%). In CMD areas *An. culicifacies* (49%) was the predominant species followed by *An. subpictus* (11%), *An. fluviatilis* (2%) and other anopheline (24%). For RR colonies the species observed were *An. culicifacies* (24%), *An stephensi* (7%), and other anopheline (40%). Among Culicine mosquitoes, *Cx. quinquefasciatus* was observed to be dominant in all SUB, CMD and RR colonies.

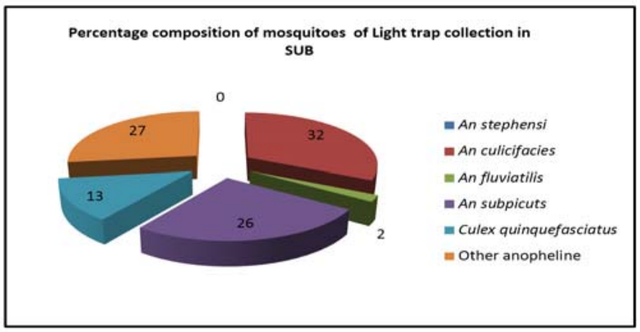

Fig 5: Percentage Composition of Vector Mosquitoes Observed In Light Trap in Submergence Areas

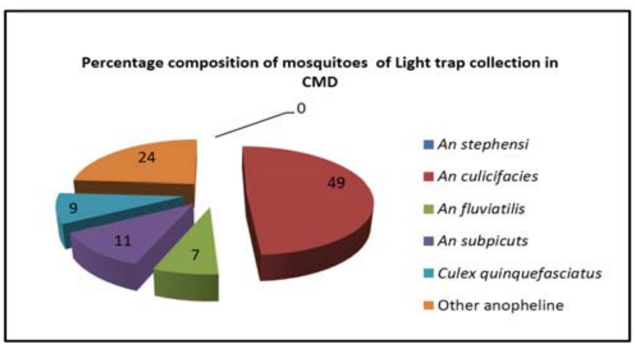

Fig 6: Percentage composition of vector mosquitoes observed in Light trap in Command areas

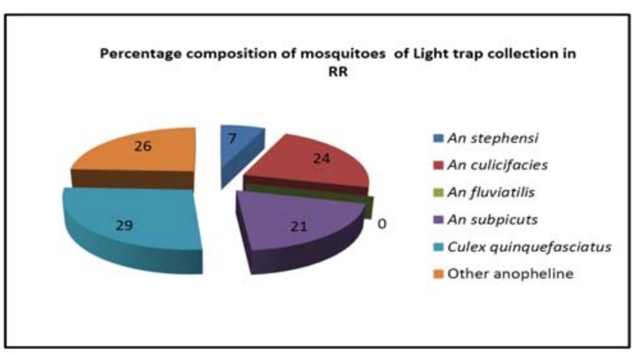

Fig 7: Percentage Composition of Vector Mosquitoes Observed In Light Trap in RR Colonies

4.3. Larval breeding

Percentage positivity of pits formed due to seepage of reservoir, wells and canal and other container indices of all the peri-domestic and domestic breeding containers were pooled for three seasons namely pre-monsoon, monsoon and post monsoon. The observations from SUB are compiled in table-1, CMD in table-2 and RR in table-3.

Table 1: Percentage positivity for reservoir pits and container indices for domestic sites in SUB areas for Jan 2013-Dec 2014

	Pre-Monsoon		Monsoon		Post-Monsoon	
Breeding Sites	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
	Percentage positivity (%)					
Downstream Pits/Pools	28.57	11.43	18.6	13.6	56.24	32.14
Upstream Reservoir/Streams Pits/Pools	32.8	17.4	84.92	67.92	33.1	12.34
Wells	80	60	40	35	64	20
	Container indices					
Plastic Containers	20.4	9.2	43.2	24.7	11.3	4.7
Cemented Tanks	43.3	22.3	82.4	26.1	32.7	13.4
Mud Pots	22.7	9.8	56.3	19.3	19.8	19.8
Iron Pots	11.4	3.2	43.6	12.3	9.8	4.3

Table 2: Percentage Positivity for Reservoir Pits and Container Indices for Domestic Sites in CMD Areas for Jan 2013-Dec 2014

	Pre-Monsoon		Monsoon		Post-Monsoon	
Breeding sites	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
	Percentage positivity (%)					
Canal Seepage	100	27.8	98.4	48.4	97.32	37.8
Streams/ground pits/ pools	37.8	19.4	96.62	34.22	93.47	33.17
Wells	100	50	100	0	0	0
	Container indices					
Cemented Tanks	38.2	18.4	52.43	22.5	27.4	11.4
Mud Pots	36.4	13.2	56.3	22.7	23.9	10.2

Table 3: Container indices for domestic sites in RR colonies for Jan 2013-Dec 2014

	Pre-monsoon		Monsoon		Post-Monsoon	
Breeding sites	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
Plastic Containers	23.4	9.27	34	19.2	11	4.2
Cemented Tanks	35.17	19.32	43.1	21.23	21	8.6
Mud Pots	11.98	4.78	28.1	18.2	0	0
Iron pots/Solid Waste	0	0	37.1	19.4	11	6.2

There was significant amount of breeding in SUB due to reservoir seepage, pits and pools formed due to it. In CMD the unlined margins and part of canal under construction was found to be positive for breeding of Anopheline. Domestic breeding was more proliferate in RR colonies.

It was observed that 80% of the peri-domestic and domestic containers were found positive for *Aedes* and *Culex* larvae while all of downstream pits from SUB and seepage of canal were found positive for *Anopheles* breeding. All positive cemented tanks and coolers were found breeding for *Aedes* larvae. Some (10%) of the cemented tanks were found positive for *An. stephensi*.

To test the difference in SUB, CMD and RR colonies for the year 2013 and 2014, a‘t’ test was used to calculate the difference in percentage positivity and container indices for years 2013 and 2014. A significant difference was observed in both percentage positivity and container indices for SUB; t (12) = 2.53, p=.016 (SUB), for CMD; t (12) = 3.97, p=.001, and for RR; t (12) = 2.17, p=.041.

5. Discussion

An. culicifacies was observed to be the dominant vector for malaria in all study areas of SUB, CMD and RR colonies. The second major vector observed in both SUB and CMD was *An. fluviatilis*. It is a highly anthropophilic vector and even its lesser prevalence can give malaria dynamics an entirely new dimension and affect local transmission. All the mosquito species prefer to breed in specific breeding grounds and are selective for specific temperature, turbidity, pH and vegetation etc [3]. Most of the Anopheline have a flight range of 1.5-3 km with some reported sporadic movements till 50 km and have ability to inhabit new water bodies for breeding [23]. Downstream pits and pools near SUB and seepage from canal in CMD were found in the normal flight range (1.5-3 km) of major vector mosquitoes observed in current study and were observed to be a major risk factor to the communities associated to these study areas. This observation is consistent to a study carried out at Manso power plant differential breeding of *An. darlingi* has been associated to increased breeding sites due to reservoir created in Brazil [24]. In other similar studies, *An. braziliensis* was reported to colonize near Tucurui dam area in Brazil after five years of construction of the dam while in India the major rural vector *An. culicifacies* was reported from areas affected with irrigational schemes of Thar Desert of Rajasthan which was not found earlier [25]. Increased breeding of *An philippinensis* eventually increasing malaria load in areas associated to dams in Bangladesh is also reported from India [26]. *An. stephensi* is known to be a urban vector of malaria [17] and its presence in cemented tanks and other cisterns of RR colonies along with *An. culificacies* can be detrimental considering the breeding sites in vicinity of these RR centers.

Vector of Lymphatic Filariasis (LF) namely *Cx. quinquefasciatus* was also observed in fair number from all study sites. The main source of breeding of *Cx. quinquefasciatus* was found to be stagnant pools for long and poor drainage system. *An. gambiae* which is also supposed to be a highly anthropophilic vector has been associated to dam and irrigation channels mainly in West Africa [27]. Resurgence of LF was also reported from Nile which was found associated to water development projects [28]. In India an integrated vector control approach was utilized to culminate the load of LF in Pondicherry by reducing vector *Cx. Quinquefasciatus* [29]. It is hence important to focus on reducing these breeding sites as a strategy of focused intervention to keep a check on LF vectors. Since water resource development and management have also been associated with several Japanese Encephalitis (JE) outbreaks and an increased density of *Cx. tritaeniorhynchus* was also associated to the rice-irrigation scheme in Mahaweli in Sri Lanka [30], its presence could have raised an alarm for control authorities but its presence was not observed during this study. It is important to note that *Aedes* larvae were found breeding in peri-domestic sites which is a major risk factor to the communities living in vicinity.

Higher proportion of *An. culicifacies* indoor as compared outdoors during light trap studies in SUB and RR colonies exhibits the endophilic behavior as reported in earlier studies also [31] but higher proportion of the same in CMD areas may be inferred as behavioral changes of *An. culicifacies* due to recent indoor residual spray done in few villages of CMD. Results of source reduction and regular check on water stagnation during construction of canals are evident from current study emphasizing its role in leading towards a sustainable development.

A larval breeding survey is an important component of formulating control strategies for disease vectors as species domestic breeding sites are easy to be checked and some success has been reported by involvement of community and larval reduction in MP [32]. The percentage positivity of both upstream and downstream pits of SUB had a tendency to increase post monsoon as the reservoir level gets down creating a lot of pits and pools with receding water while the container indices increased during monsoon as many of the villagers make cemented tanks for storage of water and also keep the containers outside the huts without proper covering. For CMD areas the percentage positivity was remarkably high round the year during 2013 and container indices followed the same trend as in SUB. As compared to both SUB and CMD areas RR colonies had lesser number of breeding sites and container indices were high during pre-monsoon. As the state health authorities were involved to channelize the stagnant water of canal during study a remarkable reduction in breeding in these channels was observed. With the help of community all the possible domestic breeding containers were emptied and villagers were sensitized for keeping a check on them. It successfully helped to curtail the domestic breeding and peri-domestic breeding of both *Aedes* and *Culex* larvae in abundance.

6. Conclusion

A systemic approach to evaluate vector prevalence in areas affected with any dam or irrigation network should be a mandate to avoid any sudden upsurge of local disease. To better control the mosquito borne diseases, regular surveillance data for site specific breeding will help to project the possible diseases in future and may prevent from some unforeseen consequences. Enhanced Information Education and Communication activities will not only help to solve current problem but also make a system efficient and prepared for any sudden upsurge in local disease load. Considering flight range of all vector mosquitoes, the construction for resettlement and rehabilitation colonies can be planned away from reservoir which would help in reducing the host-vector interaction eventually reducing the mosquito borne disease load.

7. Acknowledgment

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Ethical Clearance

No ethical issue involved.

Conflict Of Interest

There is no conflict of interest for this study as declared.

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