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Abundance & distribution of muscoid flies in tsunami - hit coastal villages of southern India during post-disaster management period

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***Background & objectives*: In the tsunami (December 2004) affected coastal villages located on southern parts of Coramandel Coast of India, seawater intrusion has created serious problems for the people. In order to assess the risk of outbreak of fly-borne diseases, a longitudinal study for one year was carried out to investigate muscoid fly abundance and their distribution in relation to various phases of relief measures in disaster-hit villages.**

***Method*: Muscoid fly density was monitored in devastated human settlements, temporary shelters, garbage dumping yards and open defaecation yards in seawater intrusion and indoors and outdoors of seawater non intrusion areas using scudder grill and sweep net at monthly intervals from February 2005 to January 2006.**

***Results*: Muscoid fly density recorded in the seawater incursion area was significantly higher, compared to that observed in the seawater non incursion area with scudder grill sampling ($F= 57.896$, df = 1, $P<0.01$) or sweep net sampling ($F= 63.6$, df = 1, $P<0.01$). Fly density in seawater non incursion area was higher during hotter months (June-July 2005) and lower during cooler months. On the contrary, the fly density in the seawater incursion areas was higher during the cooler months than in hotter months, indicating that the normal trend was upset by the tsunami.**

***Interpretation & conclusion*: Seawater incursion, crowding of tsunami victims at relief camps, accumulation of solid waste at centralized relief kitchen and temporary shelters were responsible for the sudden increase in the number of flies. However, the post-disaster relief efforts kept the situation under control, without outbreak of any vector-borne diseases.**

Key words Abundance - disaster management - muscoid flies - seawater intrusion - tsunami - villages

India recorded a disaster during the last week of 2004, which was an undersea earthquake erupted in Sumatra, triggering off tidal waves called tsunami. It battered Indonesian coast, Sri Lanka, Andaman and Car Nicobar islands and southern coast of India in the Tamil Nadu State[1]. The tsunami had not only wiped out several lives, but also affected most of the survivors. Over 1,50,000 people killed across Southeast Asian countries, 10,749 were from India[2]. Of the 13 coastal districts of Tamil Nadu, the most affected district was Nagapattinam, followed by Tanjore and Kanyakumari. The Karaikkal region, a part of Puducherry Union

Territory had also been affected by this tragic event. In Nagapattinam district, the worst affected villages were Keechankuppam, Akkaraipettai, Kallar, Vizhundhamavadi, Nagore, Poompuhar, Tranquebar; and in Karaikkal region, Chandrapadi, Karaikkalmedu and Pattinacherry. Intrusion of seawater, accumulation of carcasses and consequent post disaster activities resulted in untold miseries among the people[3-5]. As an immediate relief, people were shifted to camps, organized in public places and subsequently accommodated in temporary shelters, constructed by the government. Provisions of food and water were made to the affected people. Balaraman *et al*[6] reported the risk of outbreak of vector-borne diseases in the tsunami-hit areas. Despite the pest control measures undertaken by the State Health Authorities, profuse breeding of muscoid flies was noticed in the affected villages immediately after the tsunami[7]. The abundance of flies during the post-tsunami period with various phases of relief measures was regularly monitored in selected tsunami-hit villages for one year and the results are presented here. Fly density was also monitored in the adjoining areas, where there was no seawater intrusion, for comparison.

Material & Methods

Study areas: Of the tsunami affected areas, four worst affected villages *viz*., Keechankuppam (10^0 52.467'N, 079^0 50.119'E, 0.6-m altitude), Akkaraipettai (10^0 44.646'N, 079^0 50.839'E, 1.5 m altitude) and Thirumullaivasal (11^0 57.090'N, 079^0 49.307'E, 0.6-m altitude) from Tamil Nadu; and Pattinacherry (10^0 52.912'N, 079^o 51.012'E, 0.6-m altitude) from Karaikkal region of Puducherry UT were chosen to assess the influence of various relief measures on abundance of muscoid flies. Details of seawater inundation and disaster related events of these villages were already described[7].

Immediately after the tsunami, both government and non government organizations (NGO) carried out rescue operations. The affected people were shifted from devastated human settlement areas to relief camps organized in schools, marriage halls or temples. Both the government and the NGOs supplied cooked food, clothes, medicines, protected drinking water, *etc*., to the victims. Rescue operations were completed within a week after the tsunami and relief measures were initiated subsequently. Thereafter, temporary shelters were constructed; adjoining each of the affected villages using tin sheet, coconut or palm leaves and the affected people were accommodated gradually. The shelters were made 1.0-1.5 km away from seashore.

Piped water was supplied for drinking. Hand pumps were installed for other domestic usage. At the vicinity of each temporary shelter, toilet facilities *i.e.,* pit composting toilets were constructed. For every 30 person one toilet was made for men and women separately. Awareness on sanitation and other public health hygiene was created among the victims by the public health personnel, through door to door campaigns organized by the respective governments. Garbage dumping yards were created 2-3 km away from temporary shelters in all the villages, except in Keechankuppam and Akkaraipettai where the sites chosen were 500 m away from the shelters, as these villages were surrounded with backwater on three sides. However, the distance between temporary shelter and devastated villages varied from 900-1500 m in different villages. Space spraying of dichlorvos was carried out twice a week for the first three months, post tsunami; once a week from the fourth to sixth month and thereafter once a month. Besides, solid waste was removed and disposed at the dumping yard and either buried for composting or incinerated every two days for the first three months and once a week thereafter by the public health personnel. Besides the routine activities, intervention measures were intensified, whenever necessary.

All the tsunami-hit villages had a homogeneous, tropical maritime climate, as these were located on the Coramandel Coast. Topography was also similar in all the villages. Monthly mean minimum and mean maximum temperature varied between 28.7 and 36.7^{0}C during January 2005 and January 2006. The northeast monsoon which has a pronounced impact in these areas, starts from October and ends in December with a maximum downpour during October/November.

VCRC activities: Fly density was monitored in habitats such as devastated human settlements, temporary shelters, garbage dumping yards and open defaecation yards in tsunami-hit villages using both scudder grill[8] and sweep net[9] method at monthly interval for a period of one year *i.e*., from February 2005 to January 2006 after the tsunami. All these types of habitats were found infested with muscoid flies, due to accumulation of garbage and overcrowding of afflicted victims. Study sites were chosen based on random sampling technique. In each types of habitat, five collection sites were fixed and during every visit fly surveys were made in these spots, employing the same personnel throughout the study. For comparison, fly survey was also made in seawater non intruded zones, where human habitations were the only type of habitat found with flies. While the number of muscoid flies landed on the grill per 30 sec were counted and recorded, flies sampled using a sweep-net were transferred into a cloth cage (30 cm^3) and brought to the laboratory, anaesthetized and identified using a binocular dissection microscope (Zeiss, Germany) (Magnification - ocular lens 10x and objective ranging from 8 to 32x) and a standard key[10].

Data on number of temporary shelters, population accommodated in each shelter and quantum of garbage collection per affected village were obtained from the records maintained by the State/ UT Public Health Department. The number of temporary shelters constructed was 1143 in Keechankuppam, 845 in Akkaraipettai, 408 in Thirumullaivasal and 320 in Pattinacherry. The population accommodated in temporary shelters in these villages was 6972, 4648, 2040 and 1350, respectively. Data on number of human cases affected with fly-borne diseases, if any, were collected from the Public Health Officers, who were conducting camps in these affected villages during relief activities.

Two-way ANOVA test was performed to measure the fly density between the study villages and the habitats, considering the fly density as the dependant variable and the villages and the habitats as factors. Muscoid fly density was compared between different months during the study period using one-way ANOVA test. Following ANOVA tests, Post Hoc Test by Least Square Difference (LSD) method was used for multiple comparisons. Pearson correlation coefficient test was used to determine the relation between quantum of garbage and muscoid fly density.

Results

A total 1,012 muscoid flies, comprising eight species were collected from sweep net sampling. Their order of abundance was *Musca domestica* L (84.67%), *Musca vicina* Macquart (5.69%), *Musca sorbens* Wiedemann (2.92%), *Fannia* sp. Robineau–Desvoy (2.41%), *Calliphora erythrocephala* Robineau–Desvoy (2.11%), *Chlorops* sp. (1.51%), *Sarcophaga ruficornis* F (0.61%) and *Chrysomyia* sp. Robineau–Desvoy (0.08%).

By two-way ANOVA, interaction effect with reference to muscoid fly density (number/ grill /30 sec) between the villages and the habitats was not significant (F = 0.826, df =12, P = 0.624) and there was a significant difference only within the main effects, the villages and habitats (P<0.05) (Table I). Therefore, after removing the interaction effect, the fly density was compared between the villages as well as between the habitats. The mean density over the period of observation differed significantly (F = 3.717, df = 3, P = 0.011) between the villages (Table II). The density of muscoid flies when measured using scudder grill (flies/ grill/ 30 sec) was 26.6 ± 2.3 in Keechankuppam, 24.1 ± 2.3 in Akkaraipettai, 19.2 ± 2.2 in Pattinacherry and 16.9 ± 2.3 in Thirumullaivasal. The corresponding figures were 8.29 ± 0.7, 8.28 ± 0.7, 6.37 ± 0.6 and 5.40 ± 0.7 respectively when measured using sweep net in these villages. The rank test using LSD method indicated that while the density in Keechankuppam was not significantly different from that in Akkaraipettai, it was significantly higher (P<0.05) when compared to the other two villages, Pattinacherry and Thirumullaivasal; these two villages recorded the same level of density without any significant (P>0.05 by LSD) difference. Sweep net sampling also showed a similar trend.

The mean fly density per grill per 30 sec between the habitats surveyed in the sea water incursion area

Table I. Two-way ANOVA result on the interaction effect with reference to muscoid fly density among different villages and habitats

Source	Type II sum of squares	df	Mean square	F	Significance
Corrected model	525533.725[a]	19	27659.670	43.948	0.001
Intercept	584987.184	1	584987.184	353.487	0.001
Villages	19540.604	3	6513.535	3.929	0.008
Habitats	490651.202	4	122662.801	73.996	0.001
Village * Habitat	16428.327	12	1369.027	0.826	0.624
Error	2035655.939	1228	1657.700		
Total	3113828.000	1248			
Corrected total	2561189.663	1247			

[a] R squared = 0.205 (adjusted R squared = 0.193)

Table II. Two-way ANOVA result on the comparison of muscoid fly density among different villages

Source	Type II sum of squares	df	Mean square	F	Significance
Corrected model	509105.398[a]	7	72729.343	43.948	0.001
Intercept	584987.184	1	584987.184	353.487	0.001
Villages	18454.196	3	6151.399	3.717	0.011
Habitats	490651.202	4	122662.801	74.121	0.001
Error	2052084.266	1240	1654.907		
Total	3113828.000	1248			
Corrected total	2561189.663	1247			

[a] R squared = 0.205 (adjusted R squared = 0.193)

Table III. One-way ANOVA result on the comparison of muscoid fly density in different months

	Density	Sum of square	df	Mean square	F	Significance (*P*)
No./grill/30 sec	Between groups	895741.3	11	81431.03	60.43	0.001
	Within groups	1665448.3	1236	134.45		
	Total	2561189.7	1247			
No./ sweep	Between groups	88148.6	11	8013.51	61.01	0.001
	Within groups	162344.3	1236	131.34		
	Total	250493.0	1247			

differed significantly (F = 74.121, df = 4, $P<0.001$) (Table II). The density of muscoid flies (no./ grill/30 sec) was 53.9 ± 2.6 in temporary shelters, 34.6 ± 2.5 in garbage dump yards, 14.5 ± 2.6 in devastated human settlements, 4.4 ± 2.3 in open defecation yard and 1.0 ± 1.6 SE in non incursion areas. The corresponding figures were 18.2 ± 2.7, 13.8 ± 2.9, 6.0 ± 1.8, 1.7 ± 1.9 and 0.4 ± 0.7 respectively, when measured using sweep net in these habitats. The LSD test showed that the fly density in temporary shelter, garbage dumping yard and devastated human settlement areas was significantly higher ($P<0.001$, CI 95% 6.44-39.24) than that recorded in open defaecation yard and human habitation in seawater non intrusion area. The density was at the same level in the latter two habitats. Sweep net collections also yielded similar results, as observed with scudder grill technique.

Among the habitats, the garbage dumping yard recorded six species of muscoid flies (Fig. A); eight species were collected from the temporary shelter (Fig. B). In open defaecation yards, only *M. sorbens* and *Fannia* sp. were recorded (Fig. C), while devastated human settlements witnessed only *M. domestica* and *M. vicina* (Fig. D). In and around human habitations in seawater non incursion zone *M. domestica* was the only species recorded. Overall, *M. domestica* was the predominant species in all the habitats except in open defaecation yards.

The quantity of garbage disposed per day per village in the affected area estimated during February 2005 by the municipality/ *Panchayat* for designing a proper solid waste removal system was 1715 kg in Keechankuppam, 1268 kg in Akkaraipettai, 612 kg in Pattinacherry and 305 kg in Thirumullaivasal. There was a significant positive correlation between the quantity of garbage and muscoid fly density (r= 0.9920, P=0.001) in different villages. Overall, the muscoid fly density recorded in the seawater incursion area was significantly higher when compared to that observed in the seawater non incursion area with scudder grill sampling (F = 57.896, df = 1, $P<0.01$) or sweep net sampling (F = 63.6, df = 1, $P<0.01$).

Muscoid fly density recorded in different months during the study period was significantly different (F = 60.43, df = 11, P = 0.001) by both scudder grill and (F = 61.01, df = 11, P = 0.001) and sweep net sampling methods (Table III). The overall mean density ranged from 102.25 ± 10.71 (February 2005) to 1.82 ± 0.21 per grill per 30 sec (December 2005). The density by sweep-net collection varied between 31.94 ± 3.22 (February 2005) and 0.6 ± 0.78 (December 2005). The LSD test showed a significantly (P = 0.001, CI 95%, 7.14-39.26) higher density during the first two months post tsunami *i.e.*, February and March 2005, when centralized kitchens, catering the need of the afflicted people, were functioning in all the villages, compared

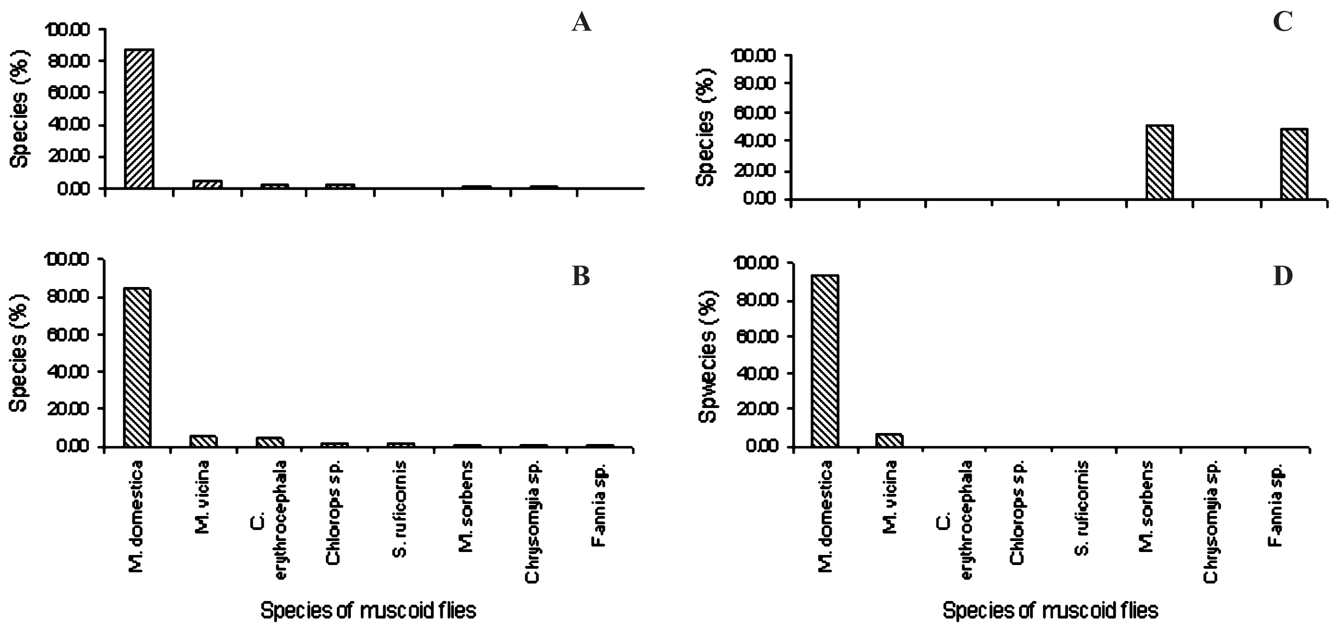

Fig. Species composition of muscoid flies in **A** garbage dumping yard; **B** temporary shelters; **C** open defaecation yard and **D** devastated human settlements.

to the density in other months. The accumulation of kitchen waste and mass supply of food were responsible for high muscoid fly density. The density declined drastically from April 2005, when supply of dry rations to the inhabitants accommodated in the temporary shelters in all villages was initiated. The declining trend was maintained till the end of the study period (January 2006) (Table IV). On the contrary, the fly density in the seawater non incursion area was higher during hotter months (June-July 2005) and lower during cooler months (February-March 2005) (Table IV). Overall the monthly muscoid fly density showed a significant declining trend (F = 12.017; P = 0.006; R^2 = 0.546) as evidenced by significant negative coefficient for months (b = -13.710; SE = 3.96; t = -3.467; P = 0.006) in tsunami hit area (Table IV), compared to unaffected areas (Table IV).

Density of *Chrysomyia* sp., *C. erythrocephala* and *S. ruficornis* were 14.0, 30.2 and 19.8 per grill per 30 sec in February 2005; and 5.2, 8.1 and 6.4 per grill per 30 sec in April 2005. When sampled using sweep net, the density during the corresponding months were 4.1, 9.9 and 6.8 per sweep and 1.9, 3.0 and 2.1 per sweep respectively. However, in January 2006 no flies of these species could be collected by either of the two methods indicating improved sanitary conditions, as a result of disaster relief measures. During the survey, no outbreak of any fly-borne diseases was reported from the temporary settlements.

Discussion

Muscoid flies, besides being a nuisance pest[11], spread disease-causing organisms by contaminating food and drinks[12]. Since, excessive fly population is not only an annoyance, but their abundance in crowded

Table IV. Density of muscoid flies in tsunami-hit coastal villages and sea water non-intruded areas

Month	Tsunami-hit coastal villages		Sea water non-intruded areas	
	Fly density		Fly density	
	(no./grill/30 sec)	No./sweep	(no./grill/30 sec)	No./sweep
February 2005	360.7	90.2	3.0	1.3
March	324.8	81.2	2.5	1.5
April	60.0	22.5	2.9	1.2
May	58.0	12.3	2.9	0.8
June	37.7	12.1	4.2	1.6
July	25.4	8.2	4.8	1.8
August	40.0	6.0	1.6	1.1
September	19.5	6.3	1.0	0.6
October	16.7	5.4	0.9	0.3
November	12.7	4.1	0.8	0.4
December	6.7	2.2	0.6	0.2
January	7.8	2.5	0.5	0.6

settlement leads to public health hazards; fly nuisance under disaster situation needs great attention[11]. Fly abundance in the tsunami-hit villages was very high immediately after the tsunami *i.e*., in January 2005 due to seawater incursion and deterioration of the environment[7]. In the present investigation, the impact of the tsunami on coastal villages was present even after two months of the disaster, as the density of muscoid flies was relatively higher during February - March 2005.

Though, all the villages studied shared similar topographical feature, muscoid fly abundance varied between villages, depending upon the extent of damage. The Keechankuppam village, which has a flat terrain with altitude of 0.6 m, witnessed the maximum damage, as it was surrounded by backwater on three sides[13]. Severe devastation with extensive seawater incursion rendered more number of people to the relief shelters, resulting in enormous quantity of garbage accumulation and thereby supporting a very high fly abundance. In the Akkaraipettai village, the level of damage was lesser, as its altitude was relatively higher and increasing from seashore to inland, but the fly nuisance was comparable to that of Keechankuppam, due to dispersal of flies from the adjacent town Nagapattinam, located 1 and 1.5 km away from Keechankuppam and Akkaraipettai respectively and the villages were adjacent to each other. Perhaps, the fly migration from the town might be responsible for the sudden spurt in density in disaster-hit villages due to enormous accumulation of garbage. Even though muscoid flies keep on moving within a village among different types of habitats, their abundance in a particular type of habitat depends upon the quantum of wet garbage accumulation. Although seawater intruded and devastated the entire area of Thirumullaivasal and Pattinacherry, each having an altitude of 0.6 m, the fly abundance was relative lower when compared to that of Keechankuppam and Akkaraipettai. The population affected and the numbers of temporary shelters were lesser in these two villages compared to other two villages, and as a consequence the amount of garbage collection and thereby the fly abundance were also less.

Although, not much information is available on seasonal abundance of muscoid flies in India, the density of flies was shown to be relatively higher, when mean minimum temperature ranged between 28 and 34^{o}C (May-July) than that observed, when the mean minimum temperature was below 28^{o}C (November-January) in coastal villages of southern India[14]. Roy and Brown[15] also observed a peak in fly abundance when the mean minimum temperature was above 28^{0}C in rural areas of northeast India. In our study also, the fly density in the seawater non intrusion areas followed a similar seasonal pattern *i.e*., high in hotter and low in cooler months. In contrast to the normal trend, the natural peak was upset by the tsunami as the fly density in the seawater incursion areas was higher during the cooler months.

In temporary shelter, the *en-masse* food preparation at centralized kitchen, accumulation of solid and liquid waste and lack of proper waste disposal system resulted in a very high fly density during February-March 2005 even when the mean minimum temperature was 28^{0} C. However, cessation of centralized kitchen facility and supply of dry rations to the households from April 2005 had resulted in a decline in muscoid fly density. Further, proper waste removal, spraying of dichlorvos and changing over from open-defaecation practice to toilet use were also accountable for reduction in fly density. Thus, the intensive and special efforts during post-disaster period kept fly population in the temporary settlements of the tsunami affected villages under control during the favourable fly breeding seasons.

In the tsunami-hit coastal areas, the density of muscoid flies recorded immediately after the tsunami (February 2005) was 60-100 times higher and after a period of 12 months post-tsunami (January 2006) was 1-4 times higher, compared to that of the tolerable level reported by the WHO[16]. Whereas, in the tsunami unaffected areas the fly density was 1-2.5 times higher than the accepted level during the survey. The muscoid fly density both the in seawater incursion and non incursion areas reached a similar level one year after the tsunami indicating restoration of normal situation.

M. domestica, most abundant immediately after the tsunami, was meager, one year after the disaster. *Chrysomyia* sp. an obligatory myiasis fly, *C. erythrocephala,* an indiscriminate feeder on organic waste of animal and plant origin and *S. ruficornis,* a facultative myiasis causing fly reduced 2.7, 3.8 and 3.1 times, respectively in April 2005 when compared to their abundance recorded in February 2005, and were completely absent by January 2006. The fly breeding habitats *i.e.*, carcasses created due to the calamity and subsequent accumulation of garbage in enormous quantity initially attracted various species of muscoid flies. Subsequently, there was a drastic reduction of density of all flies due to the post-disaster relief activities and improved sanitation measures.

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