Dengue vector control and surveillance during a major outbreak in a coastal Red Sea area in Sudan

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مكافحة العامل الناقل لحمى الضنك وترصُّده خلال فاشية كبرى في منطقة ساحل البحر الأحمر في السودان

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الخلاصـة: حدثَت في مدينة بور سودان، في السودان، في عام 2010، فاشية من حمى الضنك لم يسبق لها مثيل، إذ بلغ معدّل حدوث الضنك 94 حالة لكل 10 000 نسمة على مدى 17 أسبوعاً من الوباء (وبلغ إجمالي عدد الحالات 3765). ويعرض الباحثون في هذه الورقة خطة التصدّي لمكافحة العامل الناقل للفاشية، والتي تتضمن بشكل رئيسي تفتيش المنازل ورش الفضاء بمبيدات الحشرات. وقد بلغ العدد الإجمالي للمنازل التي خضعت للتفتيش خلال ترصُّد العامل الناقل 3048 منـزلاً، تم فيها جمع 794 19 يرقة و3240 خادرة من الزواعج المصرية، وقد تناقصت الـمَنَاسب الوبائية خلال تلك الفترة، فنقص مَنْسَب المنازل من 100٪ إلى 16٪ ($F = 57.8$, $P < 0.001$) كما نقص مَنْسَب الخوادر/ الأشخاص من 0.77 في الأسبوع التاسع إلى 0.10 ($F = 3.06$, $P < 0.01$) في الأسبوع الحادي والعشرين. وقد ترافَق هذا النقص مع نقص في عدد الحالات من ذروة بَلَغَت 340 حالة في الأسبوع الثالث عشر إلى صفر في الأسبوع التاسع والعشرين في نهاية الفاشية. ولوحِظَ ترابُط يُعْتَدُّ به إحصائياً بين المتثابتات الحشراتيَّة وبين معدّل حدوث حمى الضنك ($R^2 = 0.83$, $F = 23.9$, $P < 0.001$). إن الترصُّد الوبائي المتكامل وترصُّد العوامل الناقلة من الأمور الأساسية في البرامج الفعَّالة لمكافحة حمى الضنك.

ABSTRACT An unprecedented dengue outbreak occurred in 2010 in Port Sudan city, Sudan. Dengue incidence was 94 cases per 10 000 observed over 17 epidemiological weeks (total cases = 3 765). We report here the impact of the vector control response plan to the outbreak, which mainly entailed house inspection and insecticide space spraying. In total 3 048 houses were inspected during vector surveillance and 19 794 larvae and 3 240 pupae of *Aedes aegypti* were collected. Entomological indices decreased during the period: house index declined from 100% to 16% ($F = 57.8$, $P < 0.001$) and pupal/person (P/P) index from 0.77 to 0.10 ($F = 3.06$, $P < 0.01$) in weeks 9 and 21 respectively. This decline was accompanied by a decrease in cases from a peak of 341 cases in week 13 to zero in week 29 and the end of the outbreak. There was a significant correlation between the entomological parameters and dengue incidence ($R^2 = 0.83$, $F = 23.9$, $P < 0.001$). Integrated epidemiological and vector surveillance is essential to an effective dengue control programme

Surveillance du vecteur de la dengue et actions de lutte pendant une importante flambée dans une zone côtière de la Mer rouge au Soudan

RÉSUMÉ Une flambée de dengue sans précédent s'est produite en 2010 dans la ville de Port Soudan (Soudan). L'incidence de la dengue était de 94 cas pour 10 000 observés pendant 17 semaines épidémiologiques (nombre total de cas = 3 765). Nous présentons ici l'impact du plan de riposte visant à lutter contre le vecteur de la flambée. Ce plan consistait principalement en l'inspection des logements et la pulvérisation d'insecticides. Au total, 3 048 logements ont été inspectés pendant la surveillance du vecteur et 19 794 larves et 3 240 nymphes d'*Aedes aegypti* ont été recueillies. Les indices entomologiques ont diminué pendant la période : l'indice « habitations » est passé de 100 % à 16 % ($F = 57,8$; $P < 0,001$) et l'indice nymphe/personne est passé de 0,77 à 0,10 ($F = 3,06$; $P < 0,01$) au cours des semaines 9 et 21 respectivement. Cette diminution a été accompagnée par une diminution du nombre de cas, passant d'un pic de 341 cas en semaine 13 à zéro en semaine 29 et à la fin de la flambée. Une corrélation significative a été retrouvée entre les paramètres entomologiques et l'incidence de la dengue ($R^2 = 0,83$; $F = 23,9$; $P < 0,001$). Une surveillance vectorielle et épidémiologique intégrée est essentielle pour garantir l'efficacité d'un programme de lutte contre la dengue.

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Received: 19/06/11; accepted: 11/01/12

Introduction

Dengue is the most important arthropod-borne viral infection of humans. Worldwide, an estimated 2.5 billion people are at risk of infection, approximately 1 billion live in urban areas in tropical and sub-tropical countries in South-East Asia, the Western Pacific and the American regions of the World Health Organization (WHO) [1]. In the WHO Eastern Mediterranean Region, dengue is an emerging health problem in several countries such as Djibouti, Pakistan, Saudi Arabia, Somalia, Sudan and Yemen [2,3].

The coastal area of the Red Sea state of Sudan has been subject to repetitive outbreaks of dengue fever (DF) and dengue haemorrhagic fever (DHF) in the past decade, particularly the main port of the country, Port Sudan (19°37' N; 37°13' E) [4] National programme for Epidemics Control and Zoonotic Diseases, Sudan, unpublished data, 2010]. Three serotypes of the virus (DENV1, DENV2 and DEN3) are known to circulate [5,6], and infestations of *Aedes aegypti*, the mosquito vector, have been documented in the area [3]; this is linked to the limited drinking-water and consequent water storage habits of the local community [7]. A lack of an efficient surveillance system has resulted in delayed response to these outbreaks. Moreover, the vector control approach during these outbreaks was the same as that for a malaria outbreak. Interventions were been selected and implemented without consideration to differences in bionomics and ecology between the malaria and dengue vectors [OME Seidahmed, unpublished report, 2010].

An unprecedented dengue outbreak started in January 2010 in Port Sudan [3]. In this report, we describe how vector control and surveillance were promoted and incorporated in the response plan to the outbreak, and the operational outcomes in terms of evaluation of vector control interventions and the monitoring of the course of the outbreak.

Methods

Selection of vector control interventions

Selection of vector control interventions was based on findings of research work carried out in 2008–2009 [3]. In addition, a preliminary survey was carried out at the beginning of the outbreak in March 2010. The survey aimed to:

- explore whether another dengue vector species other than *Aedes aegypti* had infested the outbreak area, particularly where cases of DHF were reported;
- determine key breeding containers (i.e. highly productive containers with > 80% of all adult mosquitoes with the dengue vector, as determined by pupal counts);
- assess productivity of the key container(s) in relation to location (indoor or outdoor);
- explore pre-intervention entomological indices, mainly house index (HI) and pupal/person (P/P) index;
- check biting time(s) and resting site(s) of the dengue vector.

Vector surveillance

Sentinel sites & vector surveillance team

Eight sentinel sites were defined and fixed in Port Sudan city; these covered the 3 administrative division of the city: eastern (Abuhasheish, Elthora and Elgadisia), middle (downtown and Wihda) and southern sectors (Transeet, Elmatar and Darelnaeem).

Eight health workers were trained on basic water filtration and mosquito collection using water sieves, hose pipes, white-enamel trays and pipettes from typical containers (clay-pots and barrels). In addition, sweep nets were used in water filtration from large containers such as underground tanks. The training also focused on identification of key water productive containers inside houses, and counting, sorting and transfer of pupae and larvae of *Aedes* mosquito to a field laboratory in Port Sudan.

Surveys

We followed the methodology of pupal demographic surveys described by Focks and others [8]. Weekly, a total of 240 houses were randomly selected and inspected for the presence of aquatic stages of *Aedes*, i.e. 30 houses per sentinel site.

Data collection forms were reviewed by a field entomologist, packed and emailed to the Department of Medical Entomology at the National Health Laboratory in Khartoum.

Reporting

Weekly reports on density parameters of *Aedes aegypti* in relation to the human population density were produced by the senior entomologist. The entomological indices included:

- HI = percentage of houses or premises positive for *Aedes* aquatic stages
- Container index (CI) = percentage of water containers positive for *Aedes* aquatic stages
- Breteau index (BI) = number of positive containers per 100 houses in a specific location
- P/P index = total number of collected pupae/total number of inhabitants in the inspected houses.

Evaluation

The interventions were regularly evaluated and verified using both weekly reports of the vector surveillance as well as spot checks of entomological surveys and supervisory visit.

Results

Climatic conditions

Meteorological data of Port Sudan was obtained from Climate Prediction Centre, National Oceanic and Atmospheric Administration. No differences in monthly rainfall or relative humidity were shown between the outbreak period in 2010 and the same months over the 10 previous years (2000–2009) (data not shown here). However, mean minimum temperatures during January–August 2010 were markedly higher compared to the same monthly period reported in the 10 previous years (data not shown here).

Disease incidence

Dengue infections were detected using rapid dengue IgM/IgG tests, and NS1 ELISA and IgM ELISA assays. Furthermore, a subsample was sent to the National Health Laboratory for real-time polymerase chain reaction (RT–PCR) analysis. The analysis confirmed that DEN-3 was the circulating virus strain (data not shown here).

A total of 3 765 DF/DHF cases were reported in Port Sudan over 17 epidemiological weeks (27 February–25 June 2010. The total population at risk was 400 000. Hence, the incidence rate during this outbreak was 94 cases per 10 000.

Interestingly, dengue incidence was higher in the eastern and southern sectors (odds ratios = 2.44 and 2.07 respectively) compared to the middle sector (odds ratio = 1.88). However, the difference was only significant between the middle and eastern sectors ($P < 0.05$). Conversely, entomological indices (HI, CI, BI, P/P) were higher in the middle sector compared to the other 2 sectors. The difference was also significant between the middle and eastern sectors ($P < 0.05$) (Table 1).

Vector control interventions and evaluation

As a result of the preliminary survey, an array of vector control interventions was selected to work effectively against the dengue vector *Aedes aegypti*, which is NOT a malaria vector (Box 1). The vector control interventions adopted were in accordance with WHO guidelines [1]; these entailed:

- community mobilization (scrubbing and drying of unused containers by householders);
- active source reduction by health workers, particularly where DF/DHF were reported;
- focal space spraying of affected districts using a knock-down insecticide;
- larviciding of outdoor productive containers;
- distribution of long-lasting insecticide treated nets (LLINs) to the in- and outpatients.

The entire set of interventions was implemented in areas where clusters of cases were reported (transmission foci).

Coverage rates of the interventions adopted during the March–May period are presented in Table 2. The results of the evaluation work of vector control are presented in Box 2.

Vector surveillance

A total of 3 048 houses were inspected during the vector surveillance work. Vector surveys over 14 weeks resulted in collection of 19 794 larvae and 3 240 pupae of *Aedes aegypti*. Different categories of water storage containers were found in the houses. These ranged in size from small containers (< 100 L) such as jerkins to medium size (150–250 L) such as clay-pots and plastic barrels to large size (> 250 L) such as ground and underground tanks. A total of 11 524 indoor water storage containers were examined, 2 536 of which were found to be infested with larvae and/or pupae of *Aedes aegypti* (Table 3). Among all storage water containers, the key vessels containing pupae of the dengue vector were clay pots (75%) and plastic barrels (15%).

A significant decrease in the entomological indices was found during the observed period (Figure 1). HI declined from 100% to 16% ($F = 57.8$, $P < 0.001$), while the P/P index decreased from 0.77 to 0.10 ($F = 3.06$, $P < 0.01$) from the 9th to the 21st week. Accordingly, this decline was accompanied by a cessation in dengue transmission from 9 cases per 10 000 in the 13th week (341 new cases) to zero incidence in the 29th week.

Using regression analysis, a significant relationship was found between the entomological parameters and dengue incidence over the weeks of surveillance ($R^2 = 0.83$, $F = 23.9$, $P < 0.001$).

Table 1 Number of dengue cases and accompanying entomological indices in the 3 administrative sectors

Measure	Administrative sector		
	Eastern	Southern	Middle
Number of cases	1272	1291	1202
Cases OR (95% CI)	2.40^{a} (2.21–2.61)	2.07^{a,b} (1.90–2.25)	1.88^{b} (1.73–2.05)
House index (95% CI)	35.9%^{a} (31–38.9)	39.4%^{a,b} (38.5–40.6)	41.1%^{b} (37.9–44.7)
Container index (95% CI)	18.4%^{a} (16.3–20.4)	20.9%^{a,b} (18.1–24.3)	26.7%^{b} (24–29.3)
Breteau index (95% CI)	55.1^{a} (49–61.1)	62.8^{a,b} (54.1–72.7)	80.1^{b} (71.9–87.9)
Pupal/person (95% CI)	0.19^{a} (0.15–0.23)	0.22^{a,b} (0.18–0.26)	0.31^{b} (0.24–0.46)

^{a,b}Significant differences within the same row using Kruskal–Wallis test.
OR = odds ratio; CI = confidence interval.

Box 1 Summary of the vector control response plan: the aim was to contain the current outbreak using vector control interventions

Evidence (findings of the preliminary survey)	Decisions (adopted interventions)
• *Aedes aegypti aegypti* was the sole dengue vector species following Huang [15]. • House index showed high infestation rates (80%–100%) in all city districts. • Key productive containers were clay pots (75%) and plastic barrels (15%).	Community mobilization: Extensive house inspection in the whole city was carried out by community volunteers. This was augmented by a health education campaign to train and encourage household members on water filtration, and covering and scrubbing of clay pots and barrels.
• Flight range of *Aedes aegypti* is about 300–500 m. • Cases were reported from all districts (53) but were clustered in 13 densely populated districts. • Males of working age (25–40 years) were at higher risk of infection.	Active source reduction: Health workers focused on the most affected residential districts and work arenas (where clusters of cases reported) in a diameter of 500 m.
• The peak biting times of *Aedes aegypti* were: dawn (05:00–07:00), midday (11:00–13:00) and dusk (17:00–19:00). • Few resting mosquitoes were encountered during the day in walls and on edges of productive containers.	Space spraying campaign to kill infective biters with a knock-down insecticide: Trucks delivered 3 rounds per day of an ultra-low-volume spray as well as thermal fogging, particularly where dengue cases reported
• Although indoor containers are predominant in Port Sudan (> 90%), outdoor containers of non-drinking-water are present (e.g. drums of diesel).	Larviciding: Outdoor containers were treated with larvicide. These were usually dominated by Culex spp.

• From the literature:
  • Patients could be a source of propagation of infections via the mosquito.
  • The mosquito remains infective for the rest of its life after acquiring the virus.
	Prevention of internal infections: hospitalized and non-hospitalized patients were given insecticide-treated bed nets. Use of repellents was encouraged during the daytime by medical staff and care givers.

Discussion

The response to dengue outbreaks involves developing and implementing action plans that aim to break the transmission cycle of the disease. In the absence of a vaccine or drugs, vector control – including personal protective measures – is the only effective strategy to prevent and control dengue transmission [9]. At the same time, vector surveillance is an integral component in the response plan; its operational purposes entail monitoring the course of the outbreak in close coordination with epidemiological surveillance, as well as evaluating control efforts.

In this work, we showed vector control was a successful factor in the containment of the 2010 outbreak. Consequently, entomological indices were reduced. Concomitantly, a decrease in dengue cases followed and eventual cessation of the outbreak was achieved. There was a significant correlation between the entomological parameters and dengue incidence.

We think among the factors that were beyond the 2010 outbreak in Port Sudan were: i) a higher mosquito production density due to higher minimum temperatures particularly during January–March 2010 and ii) a lower immunity in the population to the DEN-3 virus strain. In the past, DEN-1 and DEN-2 were the only dengue strains that circulated in Port Sudan [4]. DEN-3 strain was detected in 2004 when an outbreak among children occurred [5].

A recent study on dengue epidemiology in Port Sudan showed that transmission is linked to the shortage and storage of drinking water. The city is subject to 2 transmission peaks: a winter peak and another major one during summer [3]. Most of the dengue outbreaks in Port Sudan occurred during summer peak (Ministry of Health, personal communication).

The incidence of dengue in the middle districts was lower than in the

Table 2 Numbers and coverage rates of the adopted interventions for dengue vector control in Port Sudan city during March–May 2010

Epidemiological week	Source reduction		Thermal fogging[a]	ULV space spraying[b]	Larviciding of outdoor breeding containers
	By volunteers[c]	By health workers			
	No. houses inspected) (% coverage)	No. houses inspected (% coverage)	No. houses (% coverage)	Area in km² (% coverage)	
10 (6–12 Mar)	41 665 (72.4%)	–	6 400 (7.0)	–	98 228 (109%)[d]
11 (13–19 Mar)		13 945 (24.2)	9 872 (10.0)	–	92 377 (102%)[d]
12 (20–26 Mar)		12 454 (21.6)	9 421 (10.0)	–	74 286 (82%)
13 (27 Mar–2 Apr)	33 722[e] (58.6%)	9 513 (16.5)	5 348 (5.0)	1 050 (85.0)	
14 (3–9 Apr)		8 492 (14.8)	6 264 (6.0)	-	
15 (10–16 Apr)		10 646 (18.5)	5 718 (6.2)	510 (41.0)	
16 (17–23 Apr)		4 000 (7.0)	3 467 (3.8)	-	
17 (24–30 Apr)		7 000 (12.2)	5 558 (6.0)	120 (9.7)	
18 (1–7 May)		8 000 (13.9)	11 434 (12.0)	_	
19 (8–14 May)		27 113 (47.1)	13 255 (14.0)	–	
20 (15–21 May)		30 077 (52.3)	13 622 (14.9)	–	
21 (22–28 May)		28 429 (49.4)	14 000 (15.5)	–	

[a] *Only applied in areas where cases were reported; then houses within a diameter of 300 m were fogged.*
[b] *Applied in lanes of districts between houses in the whole city.*
[c] *Source reduction by volunteers was evaluated every 2 weeks.*
[d] *Coverage rate surpassed the targeted number.*
[e] *13 targeted districts with clusters of reported cases (> 85% of total cases).*

eastern and southern ones. Conversely, higher entomological indices (except HI) were seen in the middle sector. There is a better water supply network in the middle sector; hence, residents of the middle sector do not usually store drinking water and this is shown by lower infestation rate (HI). However, more productive breeding containers were seen in this sector. One possible explanation for this discrepancy is that less infective biters existed in the middle sector compared to the other sectors.

There were some deficiencies in the case reporting system. These included misdiagnosis of early-onset cases and imprecise data on location of cases. To address this, the case reporting system was improved, rapid dengue IgM/IgG tests were distributed and a workshop on management of dengue cases was conducted.

Nevertheless, these problems had resulted in a delayed vector control response. If the first cases are quickly and accurately diagnosed and reported then vector control can be implemented in a timely way to prevent the spread of dengue. Despite the delayed response, the epidemiological situation in Port Sudan city dramatically improved as a result of the vector control efforts.

The vector response plan was successful because it was formulated on sound scientific evidence. This included information on the eco-epidemiology of the disease in the area as well as international experience on dengue control. However, the plan was stopped after 14 weeks for budget constraints; fortunately, this happened after the transmission cycle was interrupted. However, the cessation of the plan could have had a negative impact if it had occurred before interruption of the transmission cycle. Adverse outcomes of such a scenario might include resurgence in vector density and then incidence of DF/DHF among vulnerable groups.

Community mobilization was an integral part of the response plan. Immediate efforts were directed to source reduction carried out by volunteers. Although, the coverage rate was > 70%, no significant decrease in entomological indices was shown between pre- and post-campaigns. One of the challenges to community mobilization is compliance of household members to regularly scrub and filter their drinking containers. This requires a continuous health education programme to promote community participation. Community mobilization was successful in Vietnam but only after 9 years of intensive work. There, the programme focused on biological control combined with promoting better water management practices. These efforts have resulted in the elimination of the dengue vector in northern and central Vietnam [10].

Active source reduction by the health workers was also instigated and considerably contributed to dengue control in the targeted areas

Box 2 Evaluation of vector control interventions during the 2010 outbreak of dengue in Port Sudan, Sudan

Intervention	Activities (how this was done and supported)	Evaluation (what was learned)
Health education + House inspection campaign by community volunteers (HE+)	• Four rounds of the HE+ campaign were carried out in the whole city to: • develop recognition of aquatic stages and explain methods of source reduction (378 female volunteers from the Red Crescent, 120 male volunteers from community guards). • address control of key productive containers. • The following activities were carried out. • Pamphlets were distributed to households (34 000 in total). • Daily radio messages were broadcast. • Written messages and video clips were advertised on the streets. • Lectures of HE were conducted in 28 social and sport clubs.	• Entomological surveys showed no significant impact by HE+ (reduction rates were 1%–5% between pre- and post-campaigns) • Check on community volunteers showed the following. • Shortened message was delivered to households (drinking containers instead of water storage containers were targeted). • Pamphlets were delivered to households without training household member (only 20%–30% of houses checked after the campaigns). • About 10%–30% of the houses were locked during the campaign (residents at work or away). • The radio broadcast had low audibility in the city (5/90 persons asked).
House inspection by health workers	• Routine programme of inspection by 80 health workers was done according to a coverage timetable and in areas of reported dengue cases (Table 1).	• Good performance of health workers was assured by: • having 2 supervisors for each 15–25 health workers • sending filtrated specimens to the national health laboratory. • Entomological surveys showed significant reduction impact in targeted area (60%–70%).
Space spraying	• Rounds of space spraying were carried out (each for 7 days) (Table 1). • Indoor and outdoor thermal fogging was carried out daily. • Permethrin (Agniban 25% EC) was applied in a dosage 0.11 mg/L.	• Check supervision for space spraying campaign operations showed the following. • Many windows/doors were locked during the ultra-low-volume spraying. This was addressed using horn loudspeakers in the targeted districts. • Maintenance problems regularly caused fogging machines to be out of order. • Neither the efficacy of permethrin nor susceptibility of *Aedes* were tested before operations.
Larviciding	• Temephos (Abate) was applied in outdoor containers. Main outdoor containers were water drums of steam diesel engines.	• *Aedes* mosquito rarely breeds outdoors in Port Sudan and *Culex* spp. predominate outdoor containers.

Table 3 *Aedes aegypti* larvae/pupae infestation rate, and pupae and larvae counts by container type

Container type	No. examined (%)	No. infested with larvae/pupae (%)	Pupae count (%)	Larvae count (L1/L2) (%)	Larvae count (L3/L4) (%)
Clay pot	5715 (49.6)	1826 (72.0)	2430 (75.0)	6622 (65.0)	6916 (72.0)
Barrel	4953 (43.0)	558 (22.0)	486 (15.0)	1509 (14.8)	1921 (20.0)
Underground tanker	285 (2.5)	70 (2.8)	98 (3.0)	1019 (10.0)	480 (5.0)
Other	571 (5.0)	82 (3.2)	226 (7.0)	1038 (10.2)	289 (3.0)
Total	11 524	2 536	3 240	10 188	9 606

(coverage rate ≥ 85%). This method is usually followed during dengue outbreaks. Likewise, source reduction was carried out during the 1998 outbreak in Trinidad [11] and the 2005 outbreak in Singapore [12]. In the Singapore outbreak, "carpet combing" campaigns were carried out weekly. These campaigns involved recruiting more health workers, volunteers and town councils and resulted in removing 1000 breeding containers and containment of the outbreak [12]. On the other hand, vector control efforts failed to reduce mosquito densities beyond the transmission threshold in Trinidad; this was attributed to poor performance on active inspection [11].

In addition, 3 cycles of focal space spraying were carried out in selected districts in Port Sudan. In a systematic review of dengue control programmes, results showed that chemical interventions are ineffective, while educational campaigns seem to be effective. The review concluded that standardization of interventions, besides monitoring and

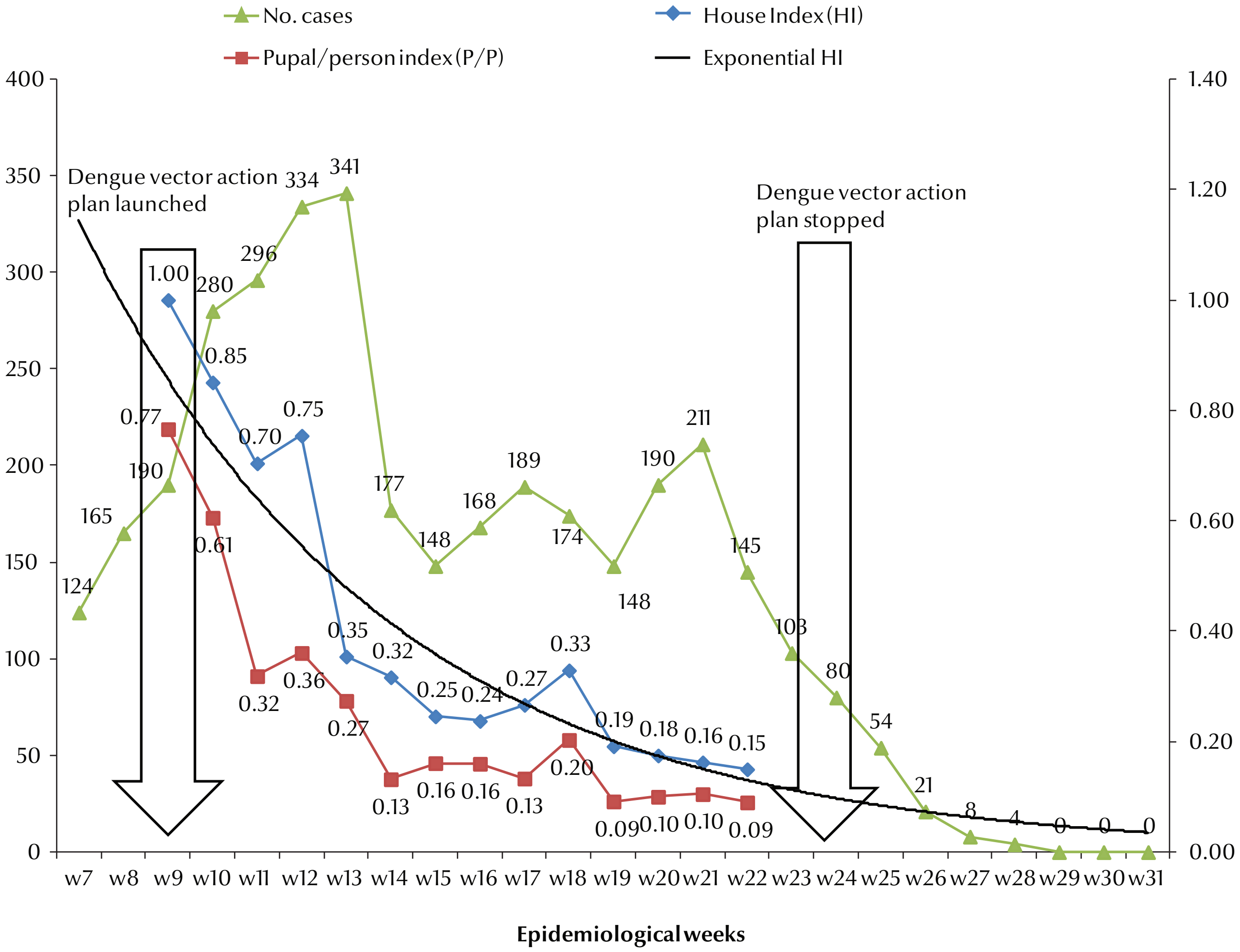

Figure 1 **Trend of dengue cases in relation to vector surveillance parameters (HI and P/P) over 25 epidemiological weeks (13/02/2010–11/06/2010) during the 2010 dengue outbreak in Port Sudan city**

evaluation, is needed [13]. However, these findings relate to non-epidemic situations. We think chemical control should be a part of response plans in the case of dengue epidemics.

In the 2010 epidemic it has been difficult to separate the effectiveness of each intervention in the containment of the outbreak as we used an integrated vector control approach. Erlanger and others reviewed the relative effectiveness of vector control interventions using entomological parameters [14]. They found integrated vector management is the most effective approach to control dengue. They suggested that vector control should use a community approach. Also, it should be tailored to the eco-epidemiological conditions of the targeted area.

During the 2010 dengue outbreak, weekly reports on the vector surveillance were generated evaluating the response plan and anticipating the situation for the upcoming weeks. The weekly report was delivered promptly to the national control programme of epidemics and state Ministry of Health.

This work clearly shows the impact of effective entomological surveillance with coordinated control intervention on dengue disease transmission. Integrated epidemiological and vector surveillance should be a cornerstone of an effective dengue control programme or integrated surveillance system for emerging arboviral diseases in Sudan.

Acknowledgements

The authors wish to thank the vector surveillance team in Port Sudan for their excellent performance. We are also grateful to the staff of federal/state Ministry of Health who worked diligently during the outbreak response activities, and to Ms Safa Hassan who participated in data entry.

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