Reduced Dengue Incidence During COVID-19 Restrictions in Sri Lanka From March 2020 to April 2021

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Abstract

Background

Dengue is a major public health concern in Sri Lanka. COVID-19 in Sri Lanka was first detected in January 2020, and has continued to be prevalent in the country since that time. The impact of public health measures imposed to restrict COVID-19 transmission on the incidence of dengue throughout the island and particularly its northern Jaffna district in the period March 2020 to April 2021 was determined.

Methods

The incidence of dengue and COVID-19, rainfall and the public health measures implemented to contain COVID-19 transmission for each district in Sri Lanka were obtained from Government sources. The Seasonal Autoregressive Integrated Moving Average (SARIMA) model was used to predict the dengue incidence expected in March 2020 to April 2021, based on pre-pandemic data and this was compared with the actual reported incidence of dengue during the period of COVID-19 restrictions. Ovitrap collections of *Aedes* larvae were also carried out in the Gurunagar ward of Jaffna city in the Jaffna district during the 2020 and 2021 lockdown and the findings compared with data from 2019.

Results

The reported number of dengue cases for the whole country from March 2020 to April 2021 was significantly lower than the numbers of dengue cases predicted from the five years immediately preceding the COVID-19 pandemic (2015-2019). Decreased numbers of dengue cases were reported compared to predicted numbers of cases in all 25 administrative districts in the country including the Jaffna district. *Aedes* larval numbers collected from ovitraps in the Gurunagar ward in Jaffna city during the COVID-19 lockdown period were decreased, with significantly lower proportions of *Ae. aegypti* than *Ae. albopictus,* compared with 2019.

Conclusion

Public health measures that restricted movement of people, closed schools, universities and offices in order to contain COVID-19 transmission unexpectedly led to a marked reduction in the incidence of dengue in Sri Lanka, in contrast to Singapore. The differences between the two tropical islands have significant implications for the epidemiology of dengue.

Background

The annual global burden of dengue has recently been estimated to be 390 million (95% confidence interval or CI of 284–528 million), with 96 million persons (95% CI of 67–136 million) manifesting clinical symptoms [1]. Approximately 70% of dengue cases occur in Asia. *Aedes aegypti* and *Aedes albopictus* are respectively the primary and secondary vectors of dengue and also vectors of other important arboviral diseases including chikungunya, yellow fever, Rift Valley fever and Zika worldwide [1–3].

Sri Lanka is a dengue-endemic tropical island in the Indian Ocean in proximity to South India and lying between latitudes 5°55' and 9°51' N and longitudes 79°41' and 81°53' E. It has a population of 21.8 million, a land area of 65,525 km^2, 25 administrative districts, and is separated by its central hills into dry and wet rainfall zones (Fig. 1). The wet zone, located in the hill country and the Southwest, receives an average annual rainfall of 250 cm in two main rainy seasons, the Northeast monsoon that normally occurs between October and December, and the Southwest monsoon that often begins in April and ends in June. Inter-monsoonal rains also occur between these periods in the wet zone. The dry zone, with an annual rainfall of 60–190 cm, receives maximal rainfall during the Northeast monsoon and typically little or no rain for the rest of the year. An intermediate zone, with mixed characteristics, lies between the dry and wet zones (Fig. 1). The densely populated districts of Colombo, Gampaha and Kalutara are located in the wet zone, while the Jaffna district in the northern Jaffna peninsula lies in dry zone (Fig. 1). The Jaffna district, with Jaffna as its largest city (population 97,000), includes most of the peninsula and nearby islands, and has a land area of 1100 km^2 with an average population density of approximately 700 persons/km^2. Although dengue has been present in Sri Lanka from the beginning of the 20th century, it has increased in prevalence throughout the island since the1990s with all four serotypes (DENV1-4) present and 105,049 cases in 2019 [4]. The established primary and secondary dengue vectors in Sri Lanka are also *Aedes aegypti* and *Ae. albopictus* respectively. Their abundance increases with monsoonal rains, and this is immediately followed by a surge in dengue cases [5–7].

Coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first detected in Wuhan, China in December 2019. COVID-19 has since spread rapidly to become a pandemic that caused approximately 168 million infections and 3.5 million deaths worldwide by 27 May 2021 [8], and severe social and economic disruption globally. The first case of COVID-19 in Sri Lanka was identified in January 2020. As of 27 May 2021, Sri Lanka is estimated to have had 172,277 cases and 1,298 deaths due to COVID-19 [8]. The first confirmed case of COVID-19 was recorded in the Jaffna district on 22 March 2020. Various public health measures (termed lockdown) to restrict COVID-19 transmission were introduced on 20 March 2020 in different districts, and these were relaxed or re-imposed with changes in COVID-19 prevalence as shown in Table 1. A total of 42,702 and 122 COVID-19 cases in the year 2020, and 63,782 and 1,304 from January to the end of April 2021 were recorded island-wide and in the Jaffna district respectively [9].

Table 1
Timeline of the public health measures used for suppressing COVID-19 transmission in 2020 and 2021 in Sri Lanka

Period	Measures	Districts Affected
1-1-2020 to 18-3-2020	None	
18-3-2020 to 20-3-2020	Curfew, compulsory wearing of face masks and maintenance of social distancing	Kalutara, Kandy and Puttalam
20-3-2020 to 20-4-2020	Nation-wide stay at home order	All
20-4-2020 to 28-6-2020	Curfew in selected districts	Colombo, Gampaha, Kalutara, Kandy, Puttalam and Kegalle
20-4-2020 to 26-5-2020	Ban on inter-district travel	All
From 11-05-2020	Partial opening of government establishments	Colombo, Gampaha, and Kalutara
26-5-20 to 28-6-2020	Inter-district public movement allowed except in Colombo and Gampaha districts	Colombo and Gampaha
From 06-06-2020	Partial opening of schools (grades 5, 11, and 13) excepting Colombo, Gampaha and Kalutara districts	All
From 23-11-2020	Partial opening of schools (grade 6 to grade 13) except in Colombo, Gampaha and Kalutara districts	All
29-10-2020 to 9-11-2020	Curfew in Colombo, Gampaha and Kalutara districts	Colombo, Gampaha, and Kalutara
1-11-2020 to 8-11-2020	Restriction on inter-district travel for people in Colombo, Gampaha and Kalutara districts	Colombo, Gampaha and Kalutara
12-12-2020 to 18-12-2020	Travel restrictions in selected areas of Galle district	Galle
From 11-01-2021	All schools opened except in Colombo, Gampaha and Kalutara districts	Colombo, Gampaha and Kalutara
From 27-03-2021	All schools and educational institutions closed nationwide	All

Dengue is a disease that has to be notified by law to public health authorities of the Ministry of Health in Sri Lanka. Physicians in the state health sector follow the dengue management guidelines developed by the Ministry of Health [10]. In the absence of specific molecular diagnostic tests in many government hospitals, dengue is generally diagnosed based on clinical symptoms and other diagnostic tests. NS1 antigen detection along with serological assays are performed only where possible. Dengue fever and dengue hemorrhagic fever are considered in the differential diagnosis of patients presenting with acute onset of fever with the following signs/symptoms: headache, especially retro-orbital pain, myalgia /arthralgia, rash (diffuse, erythematous, macular) and hemorrhagic manifestations. A full blood count is performed to investigate leukopenia, thrombocytopenia and hematocrit. Generally, the presence of fever with at least two signs and symptoms mentioned above together with thrombocytopenia are considered sufficient for a diagnosis of dengue [10, 11].

The COVID-19 pandemic was expected to divert public health resources from dengue vector control programs, and thereby exacerbate dengue transmission [12]. In this context we analyzed the numbers of officially reported dengue cases in each of the 25 administrative districts of Sri Lanka from March 2020 to April 2021 inclusive, during which period public health measures were introduced to reduce COVID-19 transmission.

Methods

Data on dengue and COVID-19 cases, and rainfall

Monthly case data for dengue from the year 2015 until April 2021, and COVID-19 from March 2020 until the end of April 2021, were obtained from the Government of Sri Lanka Epidemiology Unit web site (https://www.epid.gov.lk/web/). Monthly rainfall data for the years 2017–2020 were obtained by request from the Government of Sri Lanka Meteorological Department and the 2021 data from its official website (https://www.meteo.gov.lk/index.php?lang=en).

Predicted number of dengue cases during the COVID-19 lockdown period based on reported data for dengue cases from 2015 to 2019

Even though public health measures to contain COVID-19 transmission were implemented since 18 March, 2020, because of epidemiological and rainfall data were only available on a monthly basis, the entire period 1 March 2020 to 30 April 2021 was used in our analysis as the lockdown period. Monthly dengue cases during the COVID-19 lockdown period were compared with the predicted number of monthly dengue incidence cases based on data from the pre-pandemic period from January 2015 to February 2020 using a Seasonal Autoregressive Integrated Moving Average (SARIMA) model described previously [13]. The SARIMA model is appropriate to do the seasonal time series analysis for the monthly dengue incidence data as the dengue incidence is seasonal and closely associated with monsoonal rainfall in Sri Lanka [5–7].

We established SARIMA models (p,d,q) x (P,D,Q) (p is the autoregressive lags, d is the degree of differencing, q is the moving-average lags, P is the seasonal autoregressive lags, D is the seasonal degree of differencing and Q is the seasonal moving-average lags) for each district and for the whole island from the monthly reported dengue cases during the pre-pandemic period of 62 months from January 2015 to February 2020. SARIMA modelling and extraction of statistical parameters were performed using Python statistical libraries. A unique SARIMA (1,1,0) (1,1,1) model with the strongest correlation of predicted and actual trends (mean $R^2 > 0.7$), was selected from several models with different values of (p,d,q) x (P,D,Q) and the models from all the districts. The constructed SARIMA models used to predict dengue incidences for the 14 months from March 2020 to April 2021, during which period the different public health restriction measures shown in Table 1 were in place.

The predicted values and the actual values of dengue cases for Sri Lanka and each of the 25 districts were compared statistically for the 14 months (March 2020 to April 2021) of lockdown. Paired t-tests were conducted to determine the differences in means of reported monthly dengue cases and predicted dengue monthly cases for the whole of Sri Lanka and for each of the 25 districts. The null hypothesis of the t-test was that the means of the reported and predicted dengue cases were equal.

Rainfall and monthly numbers of dengue cases in the Jaffna district

Monthly rainfall data from January 2015 to February 2020 and the reported monthly numbers of dengue cases from January 2015 to April 2021 and the SARIMA model-predicted numbers of monthly dengue cases from March 2020 to April 2021 in the Jaffna district were used to identify variations from the pattern observed in the pre-pandemic years of 2015 to 2019 that we had reported previously [7].

Ovitrap collections and identification of Aedes larvae in Jaffna city

Ovitrap-based *Aedes* larval collections were performed in Gurunagar (9°39'12.6"N, 80°01'03.5"E), a coastal municipal ward in a densely populated residential area of Jaffna city from August 2020 to April 2021, essentially as done previously in Gurunagar in 2019 [7]. Conventional black plastic ovitraps (capacity: 650 ml, radius: 4.5 cm, height: 10 cm) containing 300 ml of water obtained from the nearest domestic water supply (i.e. well or tap) with a 2 × 15-cm plywood paddle resting against the inside upper rim were placed outside different domestic residences as described [7]. Ten ovitraps were placed and fortnightly larval collections were made. Collected *Aedes* larvae were brought to the laboratory of the Department of Zoology, University of Jaffna. Larvae were maintained here under contained insectary conditions, and emerging adult mosquitoes identified at the species level with a standard key as previously described [7].

Statistical analysis of Aedes larval collections from ovitraps

Fisher's exact test was used to determine relationships between the number of positive ovitraps in 2019 and during the 2020/2021 lockdown period separately for *Ae. aegypti* and *Ae. albopictus.* Paired t-tests were performed to compare the numbers of *Ae. aegypti* and *Ae. albopictus* collected from ovitraps during 2019 and the 2020/2021 lockdown period.

Results

Dengue incidences during COVID-19 pre-pandemic and lockdown periods in Sri Lanka

The monthly predicted (during the 14 -month lockdown period between March 2020 and April 2021) and reported numbers of dengue cases (from January 2015 to April 2021) for the whole country is shown in Fig. 2. Peaks of dengue incidence follow soon after the two monsoons and the number of cases is also influenced by the location of the populous districts of Colombo, Gampaha and Kalutara in western Sri Lanka (identified by their principal cities in Fig. 1b) that are subject to both the Southwest and Northeast monsoons [6]. The total annual numbers of reported dengue cases for each of the 25 districts and the total for the whole country from January 2015 to April 2021 are shown in Additional file S1.

Statistical analysis employing the paired t-test revealed that the reported number of dengue cases for every month in the whole of Sri Lanka was significantly less than the predicted dengue incidences for the corresponding month (Additional file S2). The paired t-test also showed that the reported total number of dengue cases for the whole of Sri Lanka ($\bar{x}$ =843.76, sd = 1135.47) for the 14-month lockdown period was significantly less ($t_{(24)}$= -5.036; *P* one-tail t- test < 0.0001) than the predicted total number of dengue cases ($\bar{x}$ =3286.61, sd = 3044.94) for the country.

Dengue incidences during pre-pandemic and lockdown periods in each district of Sri Lanka

The total numbers of predicted and reported numbers of dengue cases during the 14-month lockdown period for each of the districts is illustrated graphically in Fig. 3.

Details of district-wise monthly and total reported and predicted dengue incidence during the 14-month lockdown period are provided in additional file S3. Detailed results of the statistical analysis using paired t-tests to compare means of monthly predicted and reported numbers of dengue cases for the 14-month lockdown period from March 2020 to April 2021 of 25 administrative districts of Sri Lanka are shown in Additional file S4. The statistical analysis revealed that the reported number of dengue cases was lower than the predicted number of dengue cases in all districts, and significantly so in all districts with the exception of the Batticaloa district (Additional file S4).

Dengue incidence in relation to rainfall and public health measures to control COVID-19 in the Jaffna district

Figure 4 shows the monthly numbers of reported and predicted dengue cases in association with monthly rainfall in the Jaffna district during the five pre-pandemic years and the lockdown period. Dengue incidence in the Jaffna district is seasonal and typically increases soon after the Northeast monsoon which prevails from October to December [6, 7]. The rainfall pattern in 2020 was similar to that in the period 2015 to 2019 in the Jaffna district but the number of dengue cases reported in the Jaffna district declined in 2020 and first quarter of 2021 when compared with preceding years.

Aedes larvae collections in ovitraps from August 2020 to April 2021 in Jaffna city

In the period August 2020 to April 2021, a total of 90 and 282 *Ae. aegypti* and *Ae. albopictus* were respectively collected from the ten ovitraps in Gurunagar. A similar ovitrap collection during March – December 2019 in Gurunagar recorded 2380 and 1320 *Ae. aegypti* and *Ae. albopictus* respectively in nine ovitraps (details shown in Additional file S5). Both collections covered the Northeast monsoon of October- December, which is main rainy season in the Jaffna district due to its location in the dry zone of Sri Lanka. However, the collection in 2020 was begun in August 2020 which was approximately 15 weeks after the first introduction of COVID-19 containment measures in the country. Detailed collection data in 2020/2021 compared with 2019 (Additional file S5) show (i) a reduction in the monthly numbers of *Aedes* larvae collected in 2020 and 2021 compared with 2019; (ii) significantly decreased proportion of ovitraps with *Ae. aegypti* and *Ae. albopictus* larvae (Fisher's exact test $P < 0.0001$) in 2020 and 2021 compared with 2019 and (iii) significantly reduced number of *Ae. aegypti* per ovitrap in comparison to *Ae. albopictus* ($t_{(9)} = -2.42007$, P one-tailed t test = 0.0209) during the lockdown period, whereas significantly greater numbers of *Ae. aegypti* than *Ae. albopictus* were collected from the ovitraps in 2019 at the same location [7]

Discussion

Numerous non-pharmaceutical public health measures were introduced early in the pandemic in almost all countries to suppress the spread of COVID-19 [14]. These have been supplemented with specific vaccination that became possible at the end of 2020. Sri Lanka was no exception and imposed lockdown immediately after an increase in number of cases in March 2020. The urgent need to control COVID-19 diverts resources away from other health sector activities, including the programs to control vector-borne diseases. One of the documented impacts has been on the significant increase in the incidence and mortality from malaria during the COVID-19 pandemic period in Zimbabwe [15]. On the other hand, it is expected that infectious diseases transmitted from person to person will decrease in incidence as a result of public health measures applied to reduce COVID-19 transmission. This is borne out by marked reductions in the incidence of influenza, a major respiratory disease, in diverse countries in both the northern and southern hemispheres [16–18].

The impact of COVID-19 containment measures on the incidence of dengue has been variable with reports of increases in Thailand and Singapore [19, 20] but a decrease in Malaysia [13]. Data from the second quarter of 2020 suggested that the incidence of dengue decreased in Sri Lanka during this period [21]. Our results for the whole of the lockdown period from March 2020 to December 2020 and first quarter of 2021 nationwide and district-wise, show a significant decrease in reported number of dengue cases compared with predictions based on the preceding five pre-pandemic years.

There is epidemiological evidence to suggest that movement of people outside of their homes is one of the factors that drive the transmission of dengue virus [22], and this is also supported by mathematical modeling studies [23]. In Sri Lanka dengue vectors are highly prevalent in premises of schools, hospital, government offices, transport hubs and factories [5, 7]. The anthropophagic *Ae. aegypti* and partly anthropophagic *Ae. albopictus* exhibit two peaks of blood feeding activity in the morning and afternoon, [24], that coincide with schooling and working hours. Our findings in the Jaffna district and the rest of Sri Lanka are therefore compatible with restrictions on movement of people leading to a reduction in dengue transmission [22, 23]. However, other possible contributory factors need also to be considered: (i) Early COVID-19 and dengue manifest common clinical symptoms posing a problem for differential diagnosis [25–27]. It is therefore possible that the decrease in reported number of dengue cases in 2020 and 2021 during lockdown in Sri Lanka can also be due in part to the reluctance of people with mild dengue to seek medical treatment for fear of being identified as COVID-19 patients and quarantined; (ii) An important method for controlling dengue transmission in Sri Lanka is eliminating or minimising larval development habitats and application of larvicides by public health staff. However, these efforts were severely hampered by the COVID-19 containment measures in the Jaffna district and the rest of Sri Lanka and would therefore not have contributed to reducing the incidence of dengue in 2020 and 2021; (iii) Another possible factor is the decreased access to medical treatment (and therefore testing and recording of dengue) due to the different COVID-19 restrictions. It is likely that this also contributed to an unknown extent to the decrease in number of reported dengue cases; (iv) Movement restrictions of the population could have resulted in reduced access to human blood meals as *Ae. aegypti* and *Ae. albopictus* are both exophilic and *Ae. aegypti* is almost exclusively anthropophagic [28]. Diminished blood feeding will reduce oviposition and vector populations, particularly in the case of anthropophagic *Ae. aegypti*, which is compatible with the ovitrap collection results in Gurunagar, Jaffna city. In turn, this can reduce DENV transmission. More extensive vector data are however needed to firmly establish this possibility; (v) Rainfall is the prominent factor influencing dengue transmission in Sri Lanka and the Jaffna district [6, 7]. The pattern of rainfall in the immediate pre-pandemic period in the whole of Sri Lanka as well as the Jaffna district was not strikingly different from that in 2020 and the first quarter of 2021. This does not support a role for rainfall variation in causing the reduced incidence of dengue in Sri Lanka in 2020 and early 2021.

Our findings from Sri Lanka are in contrast with data showing that dengue transmission increased during COVID-19 restrictions in Singapore [20]. Singapore, like Sri Lanka, is a tropical island. However, Singapore is a city state with many offices located in high rise buildings and robust measures in place to limit *Aedes* vector populations, so that public transport and work places are kept relatively free of *Aedes*. Sri Lanka, in contrast has a large rural area, a considerable rural working population, longer commuting distances for workers in large cities like Colombo and less effective vector control measures in many parts of the country, including the Jaffna district [7]. Public health interventions to contain COVID-19 in Singapore were also not identical to those applied in Sri Lanka. These factors may be responsible for the different impacts of COVID-19 restrictions on the incidence of dengue between Singapore and Sri Lanka.

Conclusion

During COVID-19 prevalence, a reduction in the numbers of reported dengue cases in comparison with that predicted from the preceding five-year pre-pandemic period was seen all 25 districts of Sri Lanka, with statistically significant reductions in 24 of the 25 districts. It is proposed that this may at least partly be due to public health measures that restricted movement of people in order to contain COVID-19 transmission resulting in reduced dengue transmission.

Abbreviations

COVID-19: coronavirus disease 2019; **CI**: confidence interval; **DENV** – dengue virus; **NS1**: non structural protein 1; **SARS-COV-2**: severe acute respiratory syndrome corona virus 2

Declarations

Availability of data and materials

All data generated during this study are included in this published article and its additional files.

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Authors' contributions

SNS, RR: Conception and coordination; KS, SA, AT, TTPJ, TK, SNS: Investigation and data collection; SNS, RN, SR: Data analysis and image processing; SNS, RR: Writing the manuscript; All authors read and approved the final manuscript.

Ethics approval and consent to participate

Mosquitoes were collected in the field and reared in the insectary in accordance with the approved protocol of the Institutional Animal Ethics Committee of the University of Jaffna (AERC/2014/02). Ovitrap collections in private properties were carried out with verbal informed consent of owners of the property.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

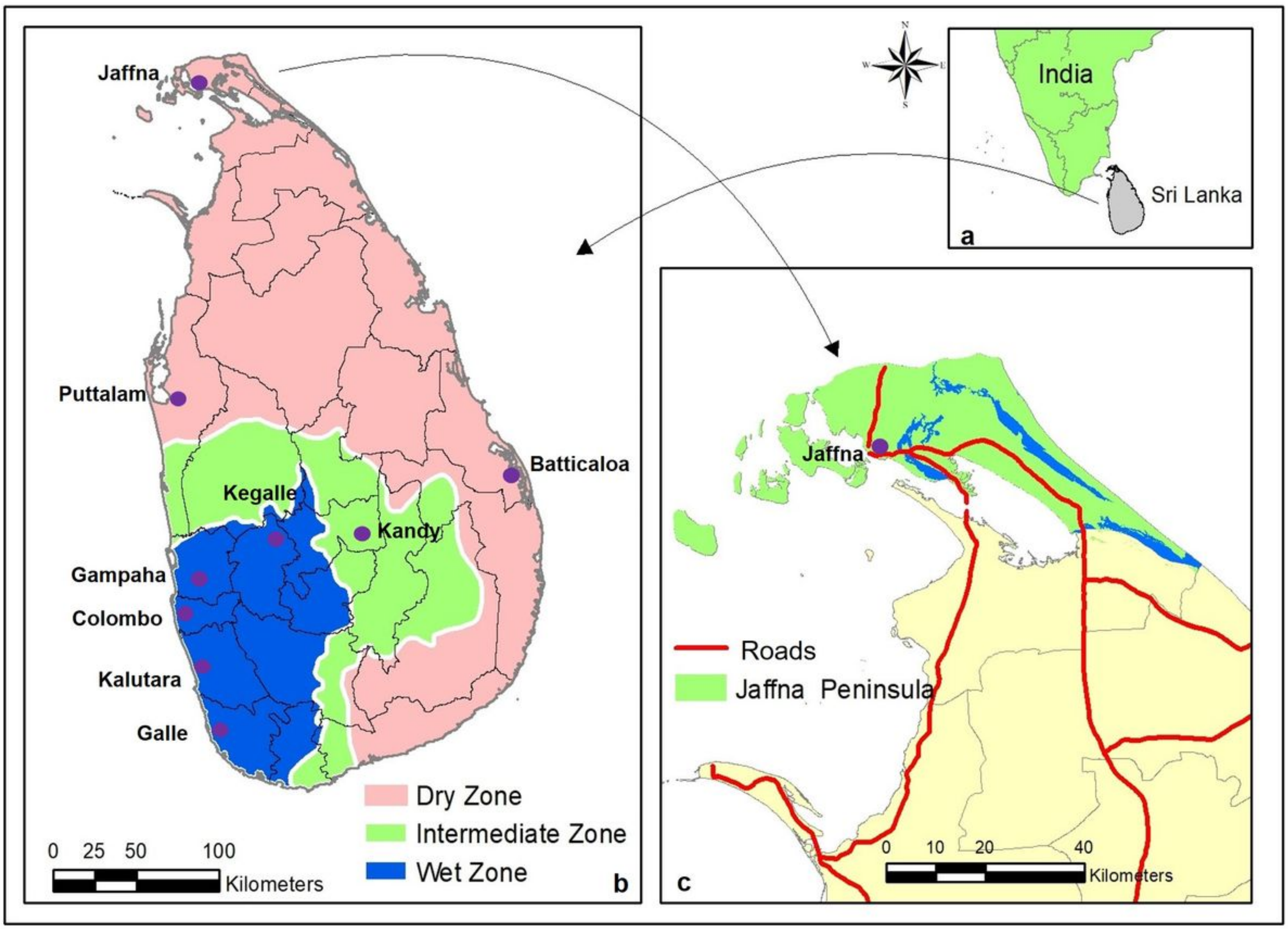

Figure 1

(a) Location of Sri Lanka in the Indian Ocean. (b) The 25 administrative districts and major cities in pertinent districts. The wet, intermediate and dry zones are demarcated. (c) Jaffna peninsula and Jaffna city in North Sri Lanka.

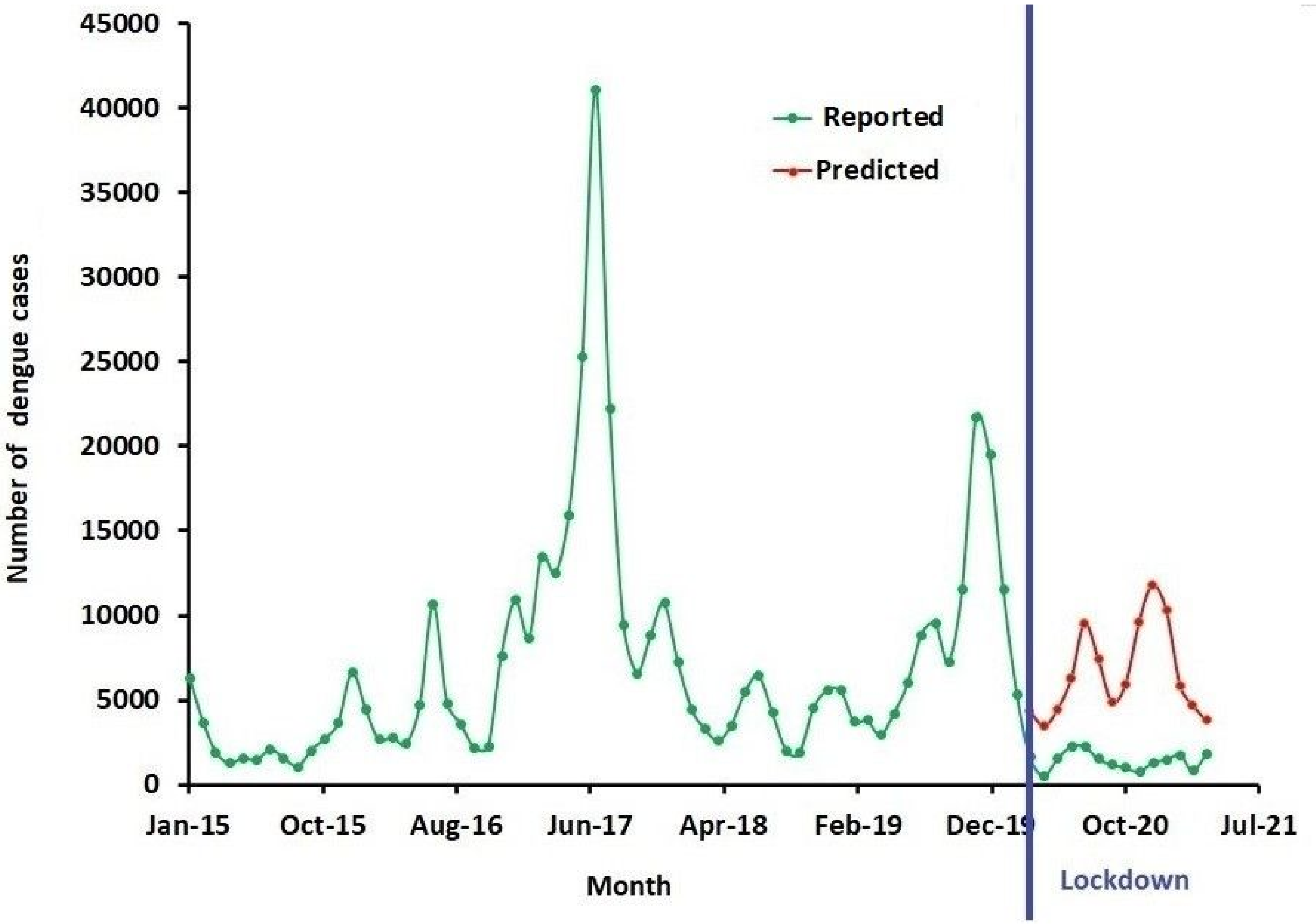

Figure 2

Reported and predicted numbers of monthly dengue cases for the whole of Sri Lanka.

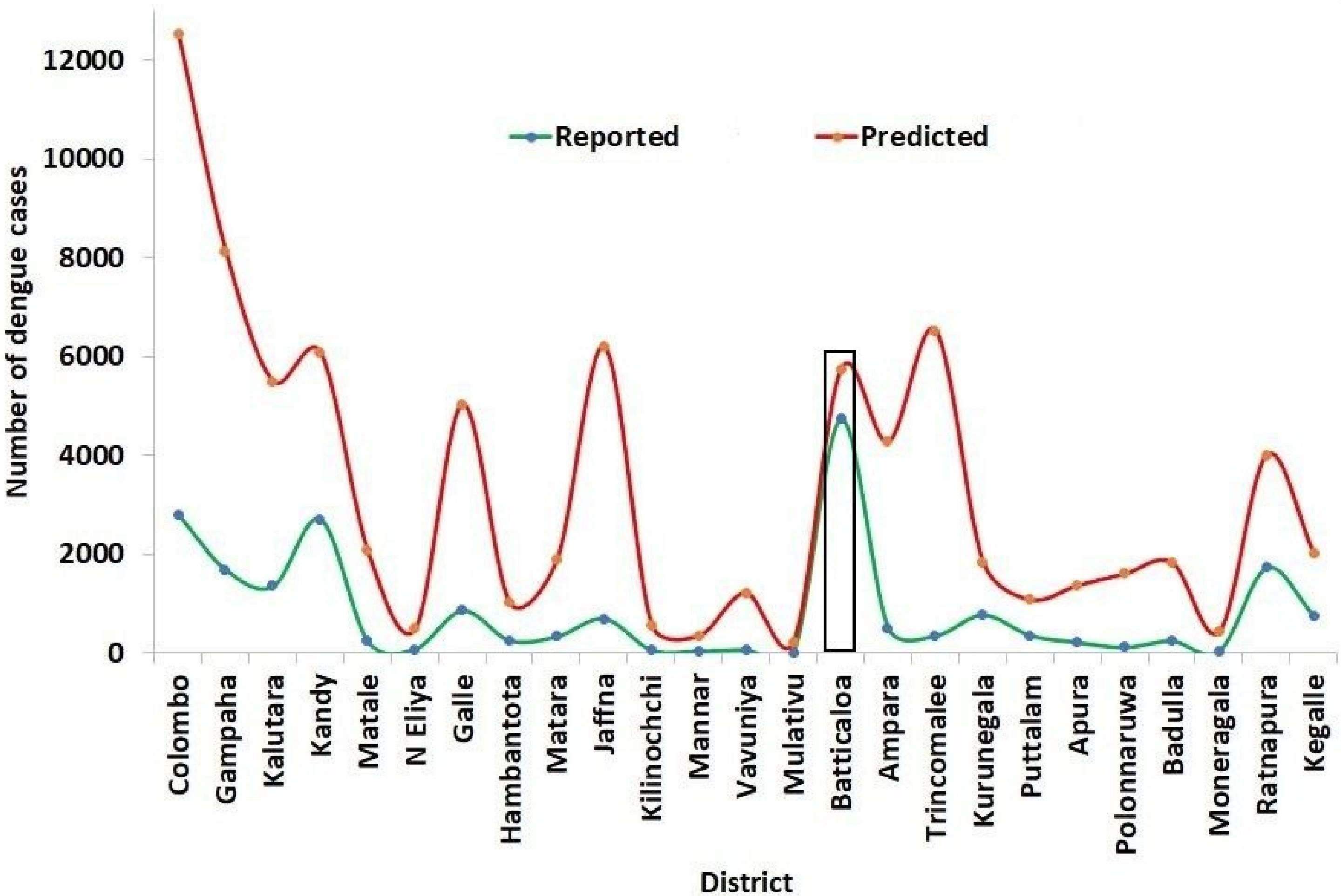

Figure 3

Reported and predicted numbers of dengue cases for each district from March 2020 to April 2021.

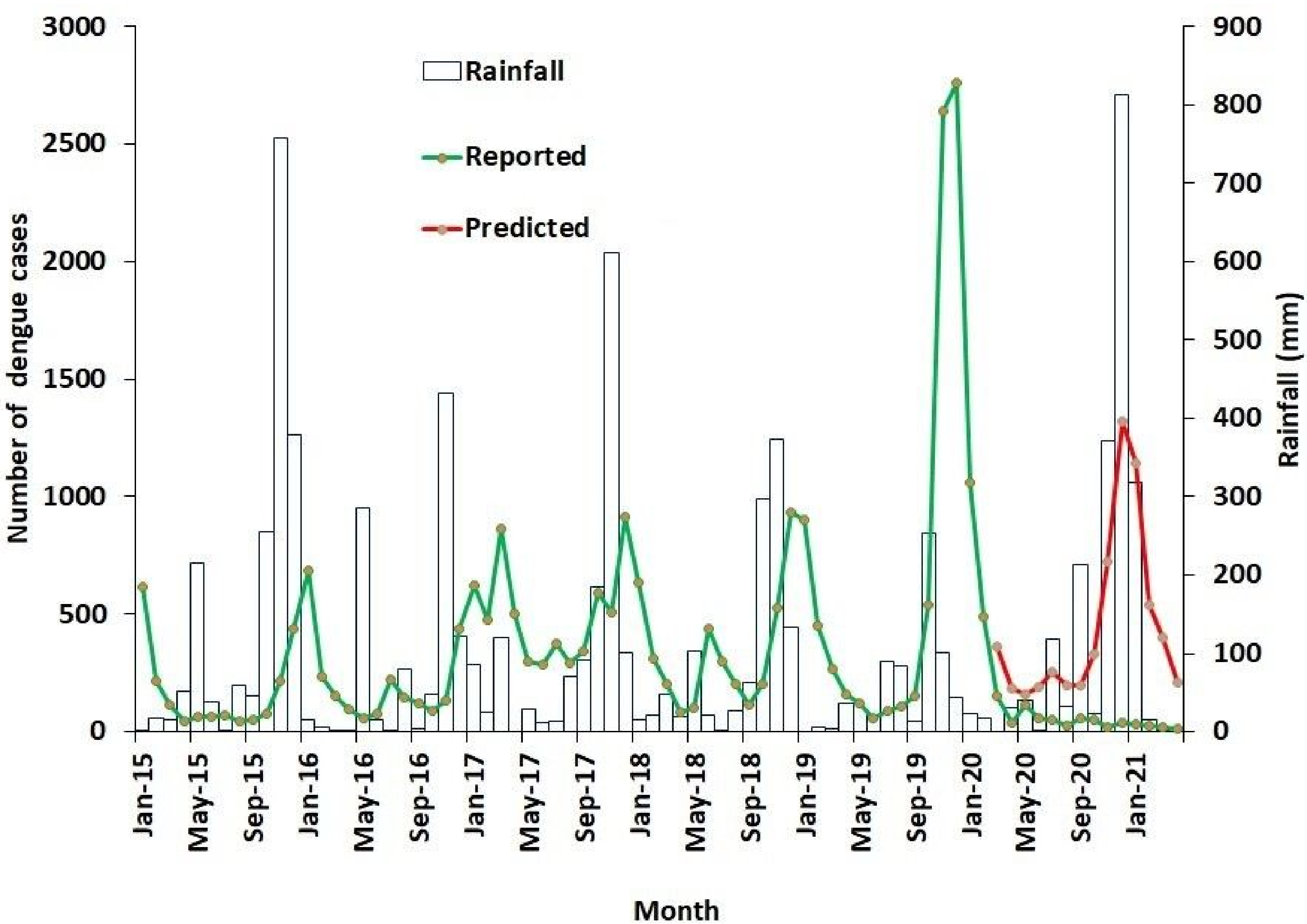

Figure 4

Reported and predicted numbers of monthly dengue cases and monthly rainfall in the Jaffna district.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AdditionalfileS1.docx
- AdditionalfileS2.docx
- AdditionalfileS3.docx
- AdditionalfileS4.docx
- AdditionalfileS5.docx