ABSTRACT

Objectives To quantify conflict events and access across countries that remain to be certified free of transmission of Dracunculus medinensis (Guinea worm disease) or require postcertification surveillance as part of the Guinea Worm Eradication Programme (GWEP).

Setting and participants Populations living in Guinea worm affected areas across seven precertification countries and 13 postcertification sub-Saharan African countries.

Outcome measures The number of conflict events and rates per 100 000 population, the main types of conflict and actors reported to be responsible for events were summarised and mapped across all countries. Chad and Mali were presented as case studies. Guinea worm information was based on GWEP reports. Conflict data were obtained from the Armed Conflict Location and Event Data Project. Maps were created using ArcGIS V.10.7 and access was measured as regional distance and time to cities.

Results More than 980 000 conflict events were reported between 2000 and 2020, with a significant increase since 2018. The highest number and rates were reported in precertification Mali (n=2556; 13.0 per 100 000), South Sudan (n=2143; 19.4), Democratic Republic of Congo (n=7016; 8.1) and postcertification Nigeria (n=6903; 3.4), Central Africa Republic (n=1251; 26.4), Burkina Faso (n=2004; 9.7). Violence against civilians, protests and battles were most frequently reported with several different actors involved including Unidentified Armed Groups and Boko Haram. Chad and Mali had contracting epidemiological and conflict situations with affected regions up to 700 km from the capital or 10 hours to the nearest city.

Conclusions Understanding the spatio-temporal patterns of conflict events, identifying hotspots, the actors responsible and their sphere of influence is critical for the GWEP and other public health programmes to develop practical risk assessments, deliver essential health interventions, implement innovative surveillance, determine certification and meet the goals of eradication.

INTRODUCTION

Guinea worm or dracunculiasis is one of two infections that have been designated formally by the World Health Assembly as diseases targeted for eradication, the other being poliomyelitis.1,3 Yaws eradication has also been included as a target in the recently approved WHO Neglected Tropical Disease (NTD) Road Map 2021–2030.4 Eradication requires Certification of each member state of the United Nations as being free of transmission of the infectious agent Dracunculus medinensis. The Guinea Worm Eradication Programme (GWEP) has more recently adopted specific definitions approved by the International Commission for the Certification of Dracunculiasis Eradication (ICCDE), which reflect the criteria required to confirm the elimination from a country and following that the need for all countries to be free of transmission prior to Global Certification of Eradication by the World Health Assembly.2 Elimination of dracunculiasis is the confirmed absence of the emergence of adult female worms (the interruption of transmission of D. medinensis) in humans
and animals for three consecutive years or longer from a country with such a low risk of reintroduction of the parasite that preventive measures could be reduced to a strict minimum. Worldwide eradication of dracunculiasis is the confirmed absence of the emergence of adult female worms (defined as compatible with the interruption of transmission of D. medinensis) in humans and animals for 3 years or longer at the global level.\(^2\)

Recently, the challenges of certifying elimination in countries and then eradication globally have been highlighted.\(^5\) While the numbers of human cases have declined by over 99% since the programme began in the late 1980s\(^7\) from an estimated 5 million cases per year to 27 cases reported to date in 2020,\(^3\) the problems of animal infections, in particular in dogs, have arisen and in Chad new modes of transmission have been uncovered involving paratenic hosts in fish, predominantly small ‘fingerlings’.\(^10\) While Chad is the most serious challenge to global eradication given the high numbers of dogs reported infected annually (over 1900 in 2019 and 1500 in 2020),\(^14\) dogs have been found infected consistently, although in small numbers in Mali, Ethiopia and Angola.\(^8\) The problems of insecurity have been a continuing part of the GWEP for as long ago as 1995 when President Jimmy Carter personally negotiated a ‘Guinea Worm ceasefire’ in South Sudan to enable all programme activities to recommence,\(^16\) while Mali has experienced heightened insecurity over recent years making access to some endemic areas difficult.\(^15\) In early 2021 the death of the President of Chad has destabilised the region and some GWEP Chad programme staff have been evacuated from the country.\(^3\)

While the challenge of animal infections is a recent phenomenon, all countries previously certified have not reported any animal infections despite surveillance in formerly endemic areas.\(^15\) However, a significant further challenge is the problem of access to insecure areas due to conflict and violence.\(^3\) Five endemic countries require to be certified together with the Democratic Republic of Congo (DRC) and Sudan, while not currently endemic, having not reported a human case since 1958 and 2002 respectively, require to be verified as free of transmission based on a visit from an International Certification Team (ICT). If access due to insecurity and conflict is curtailed or limited given the onus on any ICT is to ‘prove a negative’ as far as is possible would be impaired and would limit the validity of any report which recommended that the country was free of transmission. ‘Proving a negative’ is not possible in any public health or scientific endeavour hence the ICT missions have to balance judgements made on the basis of available information and data supplied by the country.

At present there is no standardised approach to evaluate the level of conflict risk in Guinea worm endemic countries which cover vast areas of Africa. This is critical, as conflict significantly disrupts the implementation of health service delivery, impact assessments, research and surveillance.\(^19\) In this paper, we present an approach to quantifying the risks in countries yet to be certified, as well as those already certified but require continuing surveillance until global eradication has been declared. Since elimination of transmission was confirmed by the ICCDE in some 15 countries in Africa, the security situation has changed. Civil unrest and insecurity will have impacted on the ability of countries to maintain a level of surveillance compatible with adequate postcertification scrutiny. This applies, in particular to Sahelian countries, where jihadist movements control large swathes of some countries and where national authorities have limited access or control. This is exemplified in Niger, Burkina Faso, Nigeria, Senegal, Mauritania and Cameroon whereas in Central African Republic (CAR) inter religious conflict prevents access to the area bordering Chad.\(^23\) In the DRC there is significant conflict in eastern regions of the country and the border of South Sudan and Sudan has a high level of insecurity.

To address this challenge, we examined the number of conflict events from 2000 to 2020 to highlight long-term temporal trends in countries (1) previously certified as free of transmission, (2) currently endemic (precertification countries) and (3) requiring certification but which have not recorded a case of the infection since the inception of the GWEP in the late 1980s. We quantified the number of conflict events and rates per 100 000 population for the most recent years, highlighting the main types of conflict and the main actors responsible, as well as present specific data from Chad and Mali as case studies.

**METHODS**

**Study area**

The cross-sectional study included sub-Saharan African countries that were categorised as those in the precertification stage and those in the postcertification stage. Precertification countries included those currently endemic for dracunculiasis, namely Angola, Chad, Ethiopia, Mali and South Sudan (from 2011 Independence onwards), and countries with historical evidence of Guinea worm but are yet to been certified as free from dracunculiasis, including the DRC and Sudan. Postcertification countries included Benin, Burkina Faso, Cameroon, CAR, Cote d’Ivoire, Ghana, Kenya, Mauritania, Niger, Nigeria, Senegal, Togo and Uganda. The dates when these countries were certified free of transmission are provided in Molyneux et al.\(^3\) See figure 1 for the map of precertification and postcertification countries which cover vast geographical regions of sub-Saharan Africa covering more than 15 million square kilometres (km\(^2\))\(^25\) with poor accessibility to urban centres or cities.\(^26\) The land area of each country is shown in table 1 with Angola, Chad, DRC, Mali, Niger and Sudan more than 1.2 million km\(^2\) in size.
Data sources

To examine Guinea worm status in relation to spatial and temporal distribution of conflict events and regional access within each country, several data sources were obtained:

- Guinea worm information was based on WHO annual reports and Dracunculiasis Eradication Portal,2 15 27 and GWEP reports by The Carter Centre and the Centres for Disease Control and Prevention.3 8
- Conflict data were downloaded from the Armed Conflict Location and Event Data Project (ACLED),28 29 including georeferenced location data on conflict event types categorised as battles, riots, protests, strategic developments, explosions/remote violence and violence against civilians and actors, that is, groups of people or organisations reported to be responsible for the events (definitions available on ACLED website)29 for the period from January 2000 to October 2020.
- Population data were obtained from the World Bank databank and based on 2019 estimates.25
- Administrative boundary information was obtained from the United Nations Office for the Coordination of Humanitarian Affairs.30
- Accessibility information was based on regional distance (kilometres (kms)) to the capital city and from modelled maps of ‘Accessibility to cities’, quantified as travel time in minutes (converted to hours) to the nearest high-density urban centre or city at a resolution of 1×1 km for 2015.36

These data sources represent the best available in the public domain, and it is acknowledged that there may be some missing cases and conflict event data, and differences in population estimates, country size and accessibility compared with other sources.

Patient and public involvement

No patient was included in this study.

Data analysis and mapping

Conflict and population data were downloaded, and collated, tabulated and graphed in Microsoft Excel (Microsoft, Redmond, Washington, USA) and the administrative boundary and accessibility to cities data were downloaded and imported into geographical information software (GIS) ArcGIS V.10.7 (ESRI, Redlands, California, USA) for mapping using the available GPS coordinates and descriptive analysis.

First, the number of conflict events for the precertification and postcertification countries were summarised for years from 2000 to 2020 to highlight long-term temporal trends and high-conflict Guinea worm countries.

Second, the overall number of conflict events and rates per 100,000 population for the most recent years, 2018–2020, were quantified for each country. The different types of conflict events were tabulated and mapped, and the countries with the most events and highest rates per population were identified as high-conflict countries. The main actors reported to be responsible for the highest number of events in the high-conflict countries were summarised.

Finally, the situation in Chad and Mali since 2018 was presented as contrasting case studies, and included a summary and maps of the number of Guinea worm human and/or animal cases and regions affected; the number of conflict events types and main actors in each region; and accessibility of each region measured as the distance (kms) between the centre of each region and each capital city using the Measure tool in ArcGIS, and the average time (hours) of each region to high-density urban centre or city based on data extracted using the Zonal Statistics tool in ArcGIS.

RESULTS

Overall summary 2010–2020

The total number conflict events reported for precertification and postcertification countries between 2000 and 2020 is shown in figure 2A,B (data available in online supplemental file 1). Overall, the temporal trends in conflict events across all countries were similar with a marked increase from 2010 onwards.

In the five endemic countries, a total of 18,895 conflict events were reported between 2000 and 2020 with the highest numbers in South Sudan (n=6,986 from 2011 onwards) representing 37.0% of the total. In the first decade between 2000 and 2010, a total of 2,437 events were reported, which increased 6.8-fold to 16,458 events between 2011 and 2020, with 41.5% reported in the last 3 years since 2018. In the two countries yet to be certified, a total of 30,805 events were reported with the highest

Figure 1 Map of precertification and certified countries in sub-Saharan Africa. DRC, Democratic Republic of Congo.
| Country                | Population (millions) | Land area (sq.km) | Total no of events | Total no of events/100,000 population | Events per 100,000 population |
|------------------------|-----------------------|-------------------|--------------------|---------------------------------------|------------------------------|
| **A. Precertification countries** |                       |                   |                    |                                       |                              |
| Angola                 | 24,670,000            | 124,920,000       | 8                  | 129                                  | 86                           |
| Chad                   | 1,259,200             | 12,592,000        | 15.9               | 126                                  | 108                          |
| Ethiopia               | 100,000               | 1,000,000         | 112.1              | 112                                  | 108                          |
| Malawi                 | 120,190,000           | 1,201,900         | 19.7               | 197                                  | 190                          |
| South Sudan            | 644,329               | 6,443,290         | 11.1               | 111                                  | 110                          |
| Total                  | 98,164                | 981,640           | 191                | 191                                  | 181                          |
| Democratic Republic of Congo | 2.087,050            | 20,870,050        | 86.8               | 868                                  | 860                          |
| Senegal                | 2,268                 | 22,684            | 23                 | 23                                   | 22                           |
| Sudan                  | 1,861,484             | 18,614,840        | 42.8               | 428                                  | 420                          |
| South Sudan            | 205,500               | 2,055,000         | 362                | 362                                  | 354                          |
| Total                  | 1,666,984             | 16,669,840        | 713                | 713                                  | 706                          |
| **B. Postcertification countries** |                       |                   |                    |                                       |                              |
| Benin                  | 112,760               | 11,276,000        | 11.8               | 118                                  | 116                          |
| Burkina Faso           | 2,738,000             | 27,380,000        | 20.3               | 203                                  | 200                          |
| Cameroon               | 472,710               | 4,727,100         | 25.9               | 259                                  | 256                          |
| Central African Republic | 622,900               | 6,229,000         | 4.7                | 47                                   | 46                           |
| Cote d’Ivoire          | 3,180,000             | 31,800,000        | 47.5               | 475                                  | 472                          |
| Ghana                  | 227,540               | 2,275,400         | 30.4               | 304                                  | 301                          |
| Kenya                  | 593,140               | 5,931,400         | 52.6               | 526                                  | 523                          |
| Mauritania             | 1,030,700             | 10,307,000        | 4.5                | 45                                   | 44                           |
| Nigeria                | 12,867,000            | 128,670,000       | 23.3               | 233                                  | 230                          |
| Senegal                | 212,530               | 2,125,300         | 16.3               | 163                                  | 160                          |
| Togo                   | 453,900               | 4,539,000         | 8.1                | 81                                   | 80                           |
| Total                  | 4,768,200             | 47,682,000        | 35                 | 35                                   | 34                           |

Table 1: Summary of conflict events reported in precertification and postcertification countries between 2018 and 2020.
numbers in DRC (n=17385; 56.4%). Between 2000 and 2010, a total of 6387 events were reported, which increased 3.8-fold to 24418 events between 2011 and 2020, with 41.5% reported in the last 3 years.

In the postcertification countries, a total of 48615 events were reported with the highest numbers in Nigeria (n=17763) representing 36.5% of the total. In the first decade between 2000 and 2010, the 10244 events were reported, which increased 3.7-fold to 38371 events between 2011 and 2020, with around one-third (37.3%) reported in the last 3 years.

**Summary of conflict events in recent years 2018–2020**

**Precertification countries**

In the five endemic countries where transmission of *D. medinensis* is ongoing, an overall total of 6832 conflict events were reported between 2018 and 2020 (table 1A and figure 3). The highest numbers and rates per 100,000 population were reported in Mali (n=2556; 13.0 per 100,000) and South Sudan (n=2143; 19.4 per 100,000). Overall, the most frequently reported events included violence against civilians (n=2373), protests (n=993) and battles (46.4%) and Ethiopia reporting the highest number of protests (49.8%). South Sudan also reported the highest rates of violence against civilians (8.4 per 100,000) and battles (8.6 per 100,000), and Mali the highest rates of protests (4.3 per 100,000). A summary of the actors reported to be responsible for the highest number and type of conflict events in the high-risk countries is shown in table 2A. For Mali, the actors reported for the most events included Group for Support of Islam and Muslims (Jama’at Nasr al-Islam wal Muslimin; JNIM) (n=661); Unidentified Armed Group (Mali) (n=434) and Protesters (n=261). For South Sudan, the actors included the Military Forces of South Sudan (2011-) (n=543), Unidentified Armed Group (South Sudan) (n=399) and the Sudan People’s Liberation Movement-In Opposition (n=157).

In DRC and Sudan (two countries where transmission has not been reported recently but required to be certified), a total of 10139 events were reported between 2018 and 2020 (table 1B and figure 3). The highest number and rate per 100,000 population were reported in DRC (n=7016; 8.1 per 100,000). The most frequently reported events included violence against civilians (n=3242) protests (n=2656), and battles (n=2628) with DRC reporting the highest number of these events representing 76.6%, 38.6% and 86.2% of the total, respectively. The DRC also reported the highest rates of violence against civilians (2.9 per 100,000) and battles (2.6 per 100,000), and Sudan the highest rates of protests (3.8 per 100,000) and battles (4.0 per 100,000).
Table 2. Summary of main actors reported to be responsible for the most conflict event type most in selected precertification and postcertification countries between 2018 and 2020

| Country main actor | Battles | Explosions remote violence | Protests | Riots | Strategic developments | Violence against civilians | Total no |
|--------------------|---------|-----------------------------|----------|------|-----------------------|---------------------------|---------|
| **A. Precertification countries** | | | | | | | |
| Mali               |         |                            |          |      |                       |                           |         |
| JNIM: Group for Support of Islam and Muslims | 253   | 216                         |          |      |                       |                           | 661     |
| Unidentified Armed Group (Mali) | 88   | 17                          |          | 45   | 147                   |                           | 434     |
| Protesters (Mali)  |         |                            | 259      | 2    |                       |                           | 261     |
| Fulani Ethnic Militia (Mali) | 75   | 1                           |          | 10   | 136                   |                           | 222     |
| Military Forces of Mali (2013–2020) | 48   | 8                           |          | 1    | 30                    | 78                        | 165     |
| Islamic state (Greater Sahara) | 62   | 12                          |          | 5    | 58                    | 137                       |         |
| **South Sudan**    |         |                            |          |      |                       |                           |         |
| Military Forces of South Sudan (2011-) | 362   | 10                         | 1        | 19   | 151                   |                           | 543     |
| Unidentified Armed Group (South Sudan) | 69   | 16                          |          | 7    | 307                   |                           | 399     |
| Sudan People’s Liberation Movement-In Opposition | 67   | 2                           |          | 17   | 71                    |                           | 157     |
| National Salvation Front | 67   |                            |          | 4    | 41                    |                           | 112     |
| Murle Ethnic Militia (South Sudan) | 33   |                            |          | 1    | 60                    |                           | 94      |
| Unidentified Communal Militia (South Sudan) | 18   |                            |          | 2    | 49                    |                           | 69      |
| **Democratic Republic of Congo (DRC)** | | | | | | | |
| Unidentified Armed Group (DRC) | 248   | 9                           |          | 85   | 894                   |                           | 1236    |
| Protesters (DRC)  |         |                            | 972      | 3    |                       |                           | 975     |
| Military Forces of the DRC (2019-) | 528   | 4                           |          | 1    | 70                    | 116                       | 719     |
| Allied Democratic Forces | 201  | 5                           |          | 8    | 132                   |                           | 546     |
| Rioters (DRC)     |         |                            | 534      |      |                       |                           | 534     |
| Military Forces of the DRC (2001–2019) | 302   | 2                           |          | 2    | 43                    | 58                        | 407     |
| **Sudan**          |         |                            |          |      |                       |                           |         |
| Protesters (Sudan) |         |                            | 1590     | 7    |                       |                           | 1597    |
| Unidentified Armed Group (Sudan) | 24   | 13                          |          | 2    | 8                     | 186                       | 233     |
| Rioters (Sudan)   |         |                            | 2        | 182  |                       |                           | 183     |
| Military Forces of Sudan (1989–2019) | 77   | 22                          |          | 3    | 12                    | 43                        | 158     |
| Military Forces of Sudan (1989–2019) Rapid Support Forces | 28   | 4                           |          | 4    | 3                    | 17                        | 90      |
| Darfur Communal Militia (Sudan) | 20   |                            |          | 3    | 119                   |                           | 142     |

Continued
| Country main actor                                             | Battles | Explosions remote violence | Protests | Riots | Strategic developments | Violence against civilians | Total no |
|---------------------------------------------------------------|---------|----------------------------|----------|-------|------------------------|----------------------------|----------|
| Unidentified Communal Militia (Sudan)                        | 9       |                            |          | 1     | 3                      | 102                         | 115      |
| **B. Postcertification countries**                            |         |                            |          |       |                        |                             |          |
| **Nigeria**                                                   |         |                            |          |       |                        |                             |          |
| Protesters (Nigeria)                                         |         |                            |          | 1735  |                        |                             | 1735     |
| Unidentified Armed Group (Nigeria)                           | 181     | 9                          |          | 1     | 53                     | 789                         | 1033     |
| Military Forces of Nigeria (2015-)                            | 552     | 261                        | 2        | 1     | 105                    | 44                          | 965      |
| Fulani Ethnic Militia (Nigeria)                              | 90      |                            |          | 22    | 590                    | 702                         |          |
| Rioters (Nigeria)                                            |         |                            |          | 605   |                        |                             | 605      |
| Islamic State (West Africa) and/or Boko Haram-Jamatu Ahli is-Sunnah Id-Dawatai Wal-Jihad | 236     | 57                         |          | 26    | 204                    | 523                         |          |
| **Cameroon**                                                  |         |                            |          |       |                        |                             |          |
| Islamic State (West Africa) and/or Boko Haram-Jamatu Ahli is-Sunnah Id-Dawatai Wal-Jihad | 192     | 34                         |          | 144   | 447                    | 817                         |          |
| Military Forces of Cameroon (1982-)                           | 272     | 2                          |          | 1     | 59                     | 308                         | 642      |
| Ambazonian Separatists (Cameroon)                            | 224     | 9                          |          | 55    | 175                    | 463                         |          |
| Unidentified Armed Group (Cameroon)                          | 30      | 18                         |          | 26    | 121                    | 195                         |          |
| Protesters (Cameroon)                                        |         |                            |          | 161   |                        |                             | 161      |
| Rioters (Cameroon)                                           |         |                            |          | 72    |                        |                             | 72       |
| **Central Africa Republic**                                   |         |                            |          |       |                        |                             |          |
| Unidentified Armed Group (CAR)                               | 71      | 5                          |          | 66    | 129                    | 271                         |          |
| UPC: Union for Peace in the CAR                              | 64      |                            |          | 37    | 54                     | 155                         |          |
| FPRC: Popular Front for the Renaissance of Central Africa     | 25      |                            |          | 19    | 51                     | 95                          |          |
| Anti-Balaka                                                  | 46      |                            |          | 10    | 35                     | 91                          |          |
| Protesters (CAR)                                             | 84      |                            |          | 1     |                        |                             | 85       |
| Lords Resistance Army                                        | 7       |                            |          | 23    | 52                     | 82                          |          |
| **Burkina Faso**                                             |         |                            |          |       |                        |                             |          |
| JNIM: group for Support of Islam and Muslims and/or Islamic State (Greater Sahara) | 122     | 24                         |          | 115   | 194                    | 455                         |          |
| JNIM: Group for Support of Islam and Muslims                  | 131     | 47                         |          | 50    | 112                    | 340                         |          |
| Protesters (Burkina Faso)                                    | 287     |                            |          | 8     |                        |                             | 295      |
| Military Forces of Burkina Faso (2015-)                       | 40      | 26                         |          | 25    | 89                     | 180                         |          |

Continued
A summary of the actors reported to be responsible is shown in table 2A. The main actors associated with the two most reported events in both countries included an Unidentified Armed Group (DRC=1236; Sudan=233) and Protesters (DRC=975; Sudan=1590).

**Postcertification countries**

In the postcertification countries, a total of 18,146 events (3.9 per 100,000) were reported between 2018 and 2020 (table 1B and figure 3). The highest numbers reported were in Nigeria (n=6903), Cameroon (n=2517), Burkina Faso (n=2004), and the highest rates in CAR (26.4 per 100,000), Burkina Faso (9.9 per 100,000) and Cameroon (9.7 per 100,000). The most frequently reported events included violence against civilians (n=5803) protests (n=4023), and battles (n=3891) with Nigeria reporting the highest number of these events representing 38.3%, 43.4% and 42.5% of the total, respectively. The CAR reported the highest rates of battles (7.4 per 100,000), and violence against civilians (9.7 per 100,000) and Mauritania the highest number of protests (8.5 per 100,000).

A summary of the actors reported to be responsible for the highest number and type of conflict events in the high-risk countries is shown in table 2B. For Nigeria, the actors associated with the two most reported events included Protesters (Nigeria) (n=1735) and an Unidentified Armed Group (n=1033). For Cameroon, the actors included the Islamic State (West Africa) and/or Boko Haram-Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad (n=817) and Military Forces of Cameroon (1982-) (n=642). For CAR, the actors included an Unidentified Armed Group (CAR) (n=271) and the UPC: Union for Peace in the CAR (n=155). For Burkina Faso, the actors included JNIM: Group for Support of Islam and Muslims and/or Islamic State (Greater Sahara) (n=455) and JNIM: Group for Support of Islam and Muslims (n=340).

**Chad case study**

The capital N’Djamena and six regions reporting Guinea worm human cases and/or animal infections between 2018 and 2020 are shown in figure 4A, B, together with the conflict event types reported in Chad, and the neighbouring precertification country of Sudan and postcertification countries of Cameroon, CAR and Niger.

**Guinea worm situation**

Human disease cases were reported in 2018 (n=17), 2019 (n=48) and 2020 (n=13). The areas affected included the Chari Baguirmi region, in Bailli (2018; 2019), Bousso (2018; 2019; 2020), Dourbali (2019), Kouno (2019) and Mandelia (2018; 2020) districts; the Moyen Chai region, in Danamadjji (2019), Korbal (2018; 2019) Kyabe and Sahr (2018; 2019; 2020) districts; the Salamat region, in Aboudeia (2018; 2019; 2020), Amtiman (2018; 2019) and Haraze (2019); the Tanjile region in Bere district (2018) and the Wadi-Fira region in Matadjana district (2020).

Animal infections, predominately domesticated dog infections were high and reported in 2018 (n=1040),
Conflict events
The highest number of conflict events was reported in Mopti region (n=1206) (table 3B), predominately violence against civilians (561 events) and battles (347 events) with Fulani Ethnic Militia, Groups for Support of Islam and Muslims, Unidentified Armed Group and/or Military Forces reported as the main actors associated with these events. The main conflict events in the Segou region were battles (55 events) and violence against civilians (44 events) with Group for Support of Islam and Muslims reported as the main actors associated with battles and Military Forces of Mali and Dozo Communal Militia main actors for violence against civilians.

Regional access
The level of access in terms of distance to the capital Bamako and accessibility to a city in hours within Mali and in relation to case status and conflict events is shown in table 3B. Of the Guinea worm affected regions, Mopti was the furthest from the capital Bamako, approximately 500–600 km, and had the longest accessibility time of 4.1 hours to the nearest city. Of the unaffected regions, Gao (n=503), and Tombouctou (n=264) had the highest number of conflict events, with Gao (1000–1100 km) the furthest away from the capital, and Tombouctou the longest estimated time of 62.9 hours to the nearest city.

DISCUSSION
The GWEP has made remarkable progress since activities began in the late 1980s with the WHO reporting only tens of human cases in recent years.15 27 This success has

Figure 4 Distribution of guinea worm affected areas in relation to conflict event type between 2018 and 2020 in Chad and Mali. (A) Chad affected regions. (B) Chad—close up of affected regions. (C) Mali affected regions. (D) Mali—close up of affected regions.

2019 (n=1935) and 2020 (n=1464). The areas affected included the capital N’Djamena (2018) and the Chari Baguirmi (2018; 2019), Mandoul (2018), Moyen Chai (2018; 2019), Mayo-Kebbi Est (2018; 2019) and Salamat (2018; 2019) regions (figure 4B).
been driven by country commitment, the support from the WHO and The Carter Centre and articulating the fundamental public health interventions to eliminate the transmission—case containment, control of copepods, access to safe drinking water (including filtration), regular reporting and surveillance, and instituting a reward system and the follow-up of rumours. This paper, however, documents that over the past two decades, the numbers of incidents of conflict and violence have increased dramatically, especially in the last 3 years since 2018. This is not only of concern for endemic countries, but for the two countries yet to be certified, and the 13 countries that were previously endemic for the infection requiring ongoing surveillance. The Guinea worm community have increasingly recognised that certification will face the challenges of acquiring comprehensive and reliable information in conflict zones and in accessing areas where national governments have limited control. In addition, the porosity of international borders, extensive migration generated by insecurity, intercountry range of many of the actors responsible for violence, and the need for these geographically vast countries to ensure that any Guinea worm case is recognised and reported, highlights the immense challenges programmes face to satisfy the criteria for certifying the absence of transmission and the effectiveness of surveillance.

Table 3  Summary of guinea worm status, conflict events and regional access for case study countries

| Region          | Guinea worm status | No of conflict events | Distance from N’djamena (kms) | Accessibility to city (hours) |
|-----------------|--------------------|-----------------------|-------------------------------|-------------------------------|
| A. Chad case study |                    |                       |                               |                               |
| N’Djamena       | Dog                | 104                   | –                             | –                             |
| Chari-Baguirmi  | Human/Animal       | 3                     | 100–200                       | 3.4                           |
| Moyen-Chari     | Human/Animal       | 4                     | 500–600                       | 3.5                           |
| Salamat         | Human/Animal       | 4                     | 600–700                       | 10.4                          |
| Tandjii         | Human              | 13                    | 300–400                       | 3.7                           |
| Mayo-Kebbi Est  | Dog                | 7                     | 200–300                       | 2.8                           |
| Mandoul         | Dog                | 0                     | 400–500                       | 1.8                           |
| Barh-El-Gazel   | No reports         | 1                     | 300–400                       | 11.2                          |
| Batha           | No reports         | 3                     | 400–500                       | 8.6                           |
| Borkou          | No reports         | 7                     | 600–700                       | 23.3                          |
| Ennedi Est      | No reports         | 6                     | 1000–1100                     | 35.2                          |
| Ennedi Ouest    | No reports         | 3                     | 900–1000                      | 30.8                          |
| Guera           | No reports         | 1                     | 400–500                       | 4.9                           |
| Hadjer-Lamis    | No reports         | 8                     | 100–200                       | 3.8                           |
| Kanem           | No reports         | 3                     | 300–400                       | 14.1                          |
| Lac             | No reports         | 88                    | 100–200                       | 4.9                           |
| Logone Occidental | No reports       | 8                     | 300–400                       | 1.9                           |
| Logone Oriental | No reports         | 6                     | 400–500                       | 1.9                           |
| Mayo-Kebbi Ouest| No reports         | 21                    | 300–400                       | 2.9                           |
| Ouadd           | No reports         | 57                    | 600–700                       | 4.1                           |
| Sila            | No reports         | 12                    | 700–800                       | 7.2                           |
| Tibesti         | No reports         | 55                    | 900–1000                      | 42.1                          |
| Wadi Fira       | Human              | 7                     | 800–900                       | 7.6                           |

B. Mali case study

| Region          | Distance from Bamako (kms) |
|-----------------|-----------------------------|
| Bamako          | –                           |
| Mopti           | 1206                        |
| Segou           | 145                         |
| Gao             | 503                         |
| Kayes           | 62                          |
| Kidal           | 92                          |
| Koulikoro       | 63                          |
| Menaka          | 15                          |
| Sikasso         | 58                          |
| Tombouctou      | 264                         |

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responsible for violence at both national and local levels and their motivations are different, even within the same region.28 29 Understanding how these challenges for the GWEPS can be overcome is essential if the country elimination objective and global eradication certification is to be achieved. Providing detailed data, as described in this paper, is necessary so risk assessments can be made to safely operationalise field work, especially in remote locations where access is limited.20 31 This underscores the value of understanding the spatial and temporal patterns of conflict, identifying hotspots, the actors responsible and their sphere of influence. This information will allow the potential impact of violence on GWEPS activities to be assessed consonant with the need to satisfy the robust criteria established by WHO a country to be certified by the ICCDE based on the information in the detailed national report submitted to WHO, and on which the ICT to base their assessments on the likelihood of the country being free of D. medinensis transmission. WHO and the Carter Centre should avail itself of the real-time data available from ACLED to evaluate the challenges and risks to programme staff and in planning certification missions, WHO, should seek to acquire Guinea worm relevant information from areas designated to be of high risk security by country UN Security Advisors as innovative means of acquiring the necessary information for certification will be required.

We have summarised in detail the magnitude, geographical extent and increasing incidence of conflict and violence in those countries where Guinea worm remains a problem for those responsible for ensuring a successful endgame for eradication, which now has a target of 2030 for global certification.4 The scale of the challenge can probably best be illustrated by the fact the that the total area of precertification countries is similar to continental USA.35 This WHO NTD Road Map target implies that all countries that remain to be certified must have zero cases in humans and animals by 2026/2027 as a minimum of 3 years is required of zero global cases must be reported over the period 2027–2030. This will require intense integrated human and animal surveillance, in countries at present suffering conflict events, with a trend that is regrettable accelerating rather than diminishing. The Chad and Mali case studies highlight the multifaceted epidemiological and conflict situations, the challenging access and safety issues, which will require bespoke risk assessments and innovative strategies to reach certification. A One Health approach including human, animal and environmental components should be considered given the evolving modes transmission,32 33 taking the cost-effectiveness34 and conflict context into account.

The case and conflict event data used in this study are available from ACLED to evaluate the challenges and risks to programme staff and in planning certification missions, WHO, should seek to acquire Guinea worm relevant information from areas designated to be of high risk security by country UN Security Advisors as innovative means of acquiring the necessary information for certification will be required.

We have summarised in detail the magnitude, geographical extent and increasing incidence of conflict and violence in those countries where Guinea worm remains a problem for those responsible for ensuring a successful endgame for eradication, which now has a target of 2030 for global certification.4 The scale of the challenge can probably best be illustrated by the fact the that the total area of precertification countries is similar to continental USA.35 This WHO NTD Road Map target implies that all countries that remain to be certified must have zero cases in humans and animals by 2026/2027 as a minimum of 3 years is required of zero global cases must be reported over the period 2027–2030. This will require intense integrated human and animal surveillance, in countries at present suffering conflict events, with a trend that is regrettable accelerating rather than diminishing. The Chad and Mali case studies highlight the multifaceted epidemiological and conflict situations, the challenging access and safety issues, which will require bespoke risk assessments and innovative strategies to reach certification. A One Health approach including human, animal and environmental components should be considered given the evolving modes transmission,32 33 taking the cost-effectiveness34 and conflict context into account.

The case and conflict event data used in this study are valuable resources to use as a first step in assessing a situation. However, as there are some limitations with using secondary data, it will be important that local GWEPS staff have data management and analytical skills to access, download, examine, summarise and map the data in a meaningful way to inform the programmes. Mapping skills may be developed using user-friendly open sources GIS software such as QGIS (www.qgis.org), which is free to download, has many available online training tutorials available and a range of analytical tool that can produce the same results as presented in this paper.

The methodology and tools we have used in this paper provide a better understanding of the challenges the GWEPS faces and are based on the recent studies undertaken to understand and address the risks for other NTD programmes.35 These should be more widely promoted not only for Guinea worm, but as a management and risk assessment tool for other research and health programmes working in areas and countries of complex emergencies and insecurity.

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