Revista Ibérica de Aracnología, nº **38** (30/06/2021): 152–156.
Grupo Ibérico de Aracnología (S.E.A.). ISSN: 1576 - 9518.

SPATIAL RECONQUEST OF *TRICHONEPHILA INAURATA* (WALCKENAER, 1841) IN RÉUNION AFTER VECTOR CONTROL OPERATIONS (ARANEAE: NEPHILIDAE)

Samuel Couteyen

Association Réunionnaise d'Ecologie, 188 chemin nid joli, F-97430, Le Tampon, France.
scouteyen@ecologie.re ORCID ID: S. Couteyen: 0000-0001-5589-5815

Abstract: We investigated the density of *T. inaurata* a few years after massive deltamethrin applications in an area where a major vector control operation was carried out with this insecticide in the years 2005 and 2006. We did three sampling sessions, two, three and nine years after the vector control operations. Field sampling consisted in walking along the streets of the town and reporting all the locations and number of *T. inaurata* individuals seen on both sides of the street. In 2009, we assessed the impact of Ultra Low Volume (ULV) application in 2 treated areas. The density of *T. inaurata* was significantly lower than that of *T. inaurata* in the control areas: less than 68 individuals per kilometre were sampled in treated areas, against 107 and more than 151 individuals per kilometre in control areas. At the scale of the whole study site, nine years after the treatments, both density and spatial distribution had increased very significantly. In 2008, 654 *T. inaurata* individuals were counted in the 38.85 km considered. In 2015, on the same inventory track, 3,918 *T. inaurata* were counted, which means a very significant increase. Two key factors explain this rapid recolonisation: the presence of a permanent population above 1000 m not impacted by vector control operations and ballooning by spiderlings, a very efficient means for medium and long distance dispersal. Our study shows the necessity of long term monitoring of wild fauna even in urbanised areas. We also call for an assessment of vector control efficiency and its impact on non-target species.
Key words: Araneae, Nephilidae, non target species, Ultra Low Volume, deltamethrin, ballooning, aerial dispersal, La Réunion island.

Reconquista espacial de *Trichonephila inaurata* (Walckenaer, 1841) en la isla de La Reunión después de operaciones de control de vectores (Araneae: Nephilidae)
Resumen: Se investiga la densidad de *T. inaurata* algunos años después de la aplicación masiva de deltametrina en una zona donde se efectuó una importante operación de control de vectores con dicho insecticida en los años 2005 y 2006. Se hicieron tres sesiones de muestreos, dos, tres y nueve años después de las operaciones de control de vectores. Los muestreos consistieron en caminar por las calles de la ciudad y reportar las ubicaciones y el número de individuos de *T. inaurata* observados a ambos lados de la calle. En 2009, evaluamos los impactos de las aplicaciones de volumen ultra bajo (ULV) en 2 zonas tratadas. La densidad de *T. inaurata* era significativamente más baja que la de *T. inaurata* en las zonas de control: menos de 68 individuos por kilómetro muestreado en las zonas tratadas, frente a 107 y más de 151 individuos por kilómetro en las zonas de control. A la escala del estudio completo, nueve años después de los tratamientos, tanto la densidad como la distribución espacial habían aumentado de manera significativa. En 2008, se contabilizaron 654 individuos de *T. inaurata* en los 38'85 km considerados. En 2015, en el mismo recorrido de inventario, se contabilizaron 3918 *T. inaurata*, lo que indica un aumento muy significativo. Dos factores clave explican esta recolonización rápida: la presencia de una población permanente por encima de los 1000 m no afectada por las operaciones de control de vectores y, el *ballooning* de las crías de araña, un proceso muy eficiente para la dispersión a distancias medias y largas. Nuestro estudio muestra la necesidad de una gestión a largo plazo de la fauna silvestre, incluso en las zonas urbanas. También pedimos una evaluación de la eficiencia de los controles de vectores y de su impacto sobre las especies no objetivo.
Palabras clave: Araneae, Nephilidae, especies no objetivo, volumen ultra bajo, deltametrina*, ballooning*, dispersión aérea, isla de la Reunión.

Introduction

In 2005 and 2006, a spectacular chikungunya outbreak occurred in the island of Réunion. During this outbreak, more than one third of the human population of the island was infected by the virus (Soumahoro *et al.*, 2011). The over mortality during the first months of the year 2006 was about 200 people and, no other sanitary phenomenon, but the chikungunya can explain this over mortality (Josseran *et al.*, 2011). The medical cost of this epidemic is estimated at more than €40 million (Soumahoro *et al.*, 2011).

In response to this highly serious health context, French authorities made the decision to implement a massive vector control operation targeting the mosquito *Aedes albopictus* (Skuse, 1894) responsible for the transmission of chikungunya virus. Up to 3000 people, including military forces, were mobilised in the vector control operations during the peak of the epidemic (Delatte *et al.*, 2008). To face the situation the vector control protocol evolved from 2004 to 2006. During the peak of the epidemic, from February to May 2006, the vector control protocol against adult mosquito consisted in the use of deltamethrin insecticide in all urban areas (fig. 1). The adulticide interventions was conducted following a protocol including two insecticide spreading methods, on day 0 and day+4: from the streets, applications of insecticide with Ultra Low Volume (ULV) spray machines mounted on the back of pickup trucks and day 0: in each garden, application of insecticide with Backpack Mist Blower (BMB). The application target of the active ingredient was 6g of deltamethrin per ha. From June 2006 to July 2007, adulticide protocols evolved to a lower use of ULV and BMB, with use of BMB only in the garden where owners were sick and in the neighbourhoods (Delatte *et al.*, 2008).

In 2006, AGORAH, an urban agency assessed the urban area at about 260 square kilometres (Malek Dahbi comm. pers.). In Réunion, urban areas are mostly residential areas with a great importance of gardens. However, these areas are occupied by indigenous species including *Trichonephila inaurata* (Walckenaer, 1841).

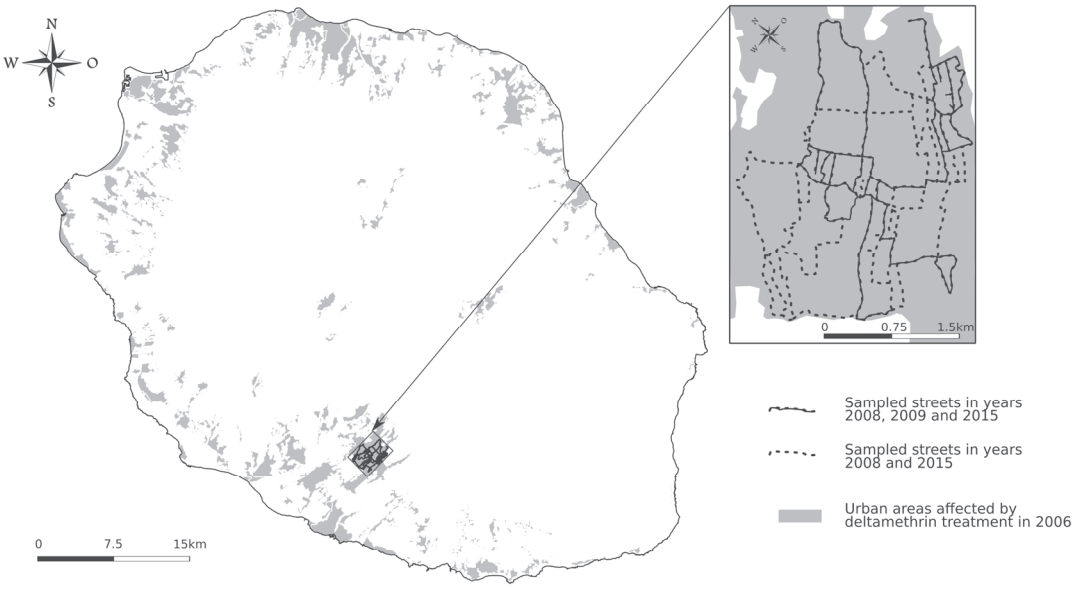


Fig. 1. Map of Réunion Island, showing urban areas affected by deltamethrin spraying in 2006 and the location of the study site, a series of streets from where *Triconephila inaurata* individuals were sampled.

In 2007, local extinction of *T. inaurata* was noticed in gardens located in urban areas concerned by vector control operation in 2006 (Couteyen, 2008). In this study, we investigate the density of *T. inaurata* a few years after massive deltamethrin applications in an area concerned by vector control in 2006 (fig. 1). We did three sampling sessions, two, three and nine years after the major vector control operations. Our goal is to assess the impact of minor vector control operations using ULV applications on *T. inaurata* which occurred in early 2009 and the way *T. inaurata* succeeded or not in recovering habitats where it was eradicated in 2006.

Materials and methods

T. inaurata is a golden orb weaving spider and one of the most frequent spiders in the Mascarene islands. This species is a good aerial disperser (Kuntner & Agnarsson, 2011). Its size and its remarkable web make it a popular species. Its life cycle lasts one year, females spawn during the dry season. Hatching occurs at the end of dry season or in early rain season, so spiderlings grow up during the rain season which is also the cyclone season. This life cycle allows spiderlings growth when food is abundant and avoids adult stage during the time when cyclones can hit the island. Indeed, the size of females and their orb webs make them vulnerable to high winds and their consequences. If ballooning is a good way for spiderlings to disperse over kilometres away from their hatching place, *T. inaurata* prematures and adults are sedentary. Once their first web built, spiders stay at the same location, only the position of the web will change as adults may weave their web to a higher place. Then, this species is a good model to investigate environmental disturbance, prematures and adults are not likely to quit the place they live in to avoid disturbance.

Study site.— Le Tampon is a town located in the southwest part of Réunion at a middle elevation, the centre of this town is at an elevation of about 550 metres. The urban area of Le Tampon is a typical "ville jardin" with a low-density housing estimated at about 5.7 qwellings per hectare in 1999 (Lajoie and Actif, 2001). Our study area is focused on the city centre and consists in a rectangular area measuring about 2.5 km by 3.5 km arranged along the slopes (fig. 1). The study area extends from 440 m to 740 m elevation high.

Field methods.— Field sampling consists in walking along the streets of the town and reporting all the locations and number of *T. inaurata* individuals seen on both sides of the street. We consider three dimensions: elevation, latitude and longitude.

Three sampling sessions were conducted:

2008: 38.8 km sampled, in an area where *T. inaurata* almost disappeared after the ULV and BMB application of deltamathrin during the Chikungunya outbreak in 2006

2009: 18.2 km sampled, included in the previous 2008 track. The purpose of this sampling is to control the data collected one year before, and to assess the impact of ULV application, two areas included in the 2008 sampling zone were treated in early 2009. To assess a possible impact of ULV application on spider density, each treated area is compared to a control area with similar size and elevational range (fig. 2):

-Area 1 (A1): sprayed area, 2.53 km sampled, elevation from 635 m to 670 m

-Control Area 1 (C1): unsprayed area, 2.56 km sampled, divided into two parts situated on either side of A1: a 0.7-km long control area, elevation from 675 to 720 m and a 1.85-km long control area, elevation from 600 m to 640 m.

-Area 2 (A2): sprayed area, 0.55 km sampled, elevation from 635 m to 695 m

-Control Area 2 (C2): unsprayed area, 0.58 km sampled, elevation from 655 to 700 m

2015: same sampling track as in 2008. The purpose is to assess the distribution variation of *T. inaurata* seven years later.

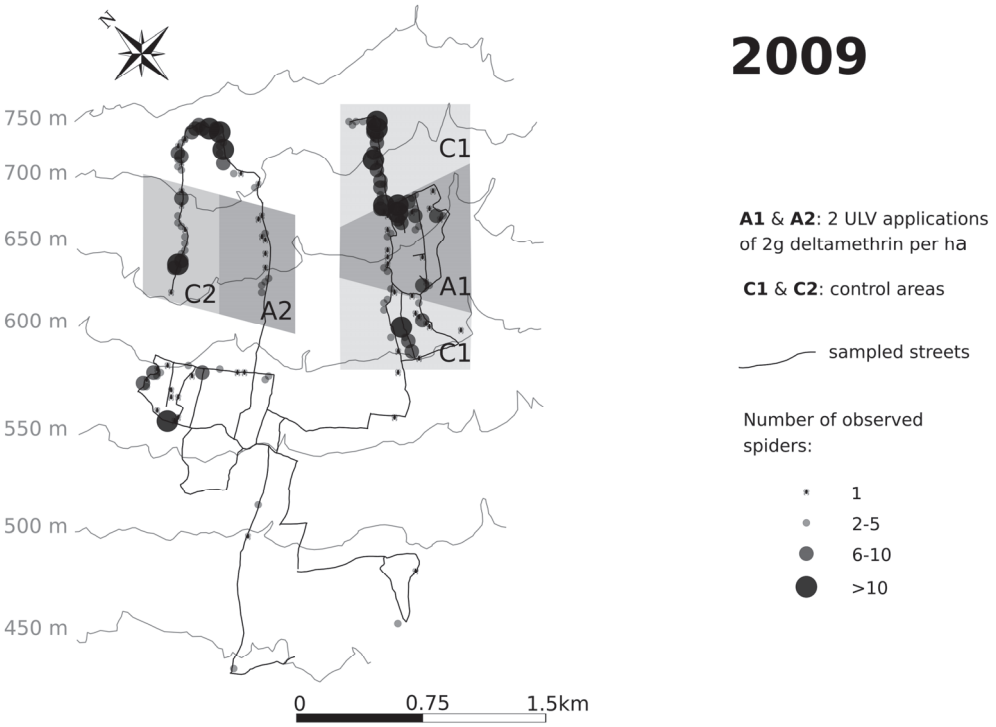


Fig. 2. *Trichonephila inaurata* distribution along 18.18 km of sampled streets in 2009. Dark grey plots have been concerned by 2 ULV applications, light grey plots are associated to control areas.

Table I. Number of *Trichonephila inaurata* encountered by km in Deltamethrin sprayed areas and in control areas. Significant comparisons are shown by * (p<0,05)

ULV application dates	Monitoring dates	*T. inaurata* encountered by km	
		in treated areas	in control areas
02, 05 II 2009	day + 64	66.3	107.0*
29 III, 01 IV 2009	day + 19	67.7	151.6*

Table II. Number of *Trichonephila inaurata* individuals observed depending on elevation during field observations in the years 2008 and 2009. Very highly significant comparisons are shown by *** (p<0,001)

	Elevation range (m)						
	< 500	500 - 549	550 - 599	600 - 649	650 - 699	> 700	total
Prospected distance (km)	2.85	1.98	5.34	3.67	2.71	1.61	**18.18**
Number of Nephila inaurata individuals observed in 2008	0	1	29	101	256	168	**555**
Number of Nephila inaurata individuals observed in 2009	7	4	26	141	280	271	**729*** **

Table III. Number of *Trichonephila inaurata* individuals observed depending on elevation during field observations in the years 2008 and 2015. Very highly significant comparisons are shown by *** (p<0,001)

	Elevation range (m)							
	< 450	450 - 499	500 - 549	550 - 599	600 - 649	650 - 699	> 700	total
Prospected distance (km)	2.4	7.8	6.1	9.3	7.1	4.6	1.7	**38.85**
Number of Nephila inaurata individuals observed in 2008	1	2	7	57	153	332	102	**654**
Number of Nephila inaurata individuals observed in 2015	91	228	309	727	699	1025	839	**3918*** **

Results

Impact of ULV aerosol application of deltamethrin on *T. inaurata* density

The 2009 sampling tracks included two areas which had been each targeted by two ULV misting treatment of 2g deltamethrin per ha earlier in the year: Area 1 (A1), 2 and 5 February; Area 2 (A2), 29 March and 1 April (fig. 2).

Area 1: We assessed the density of *T. inaurata* 64 days after the two ULV treatments. Inside this area, the density of *T. inaurata* was significantly lower than the density in control area (Table I, Student's t-test: p=0.032)

Area 2: We assessed the density of *T. inaurata* 15 days after the two ULV treatments. Also here, the density of *T. inaurata* was significantly lower than the density in control area (Table I, Student's t-test: p=0.012)

The densities observed in the two areas concerned by ULV applications were not different (Student t-test: p=0.91), in the same way, densities in the control areas couldn't be distinguished (Student t-test: p=0.19).

Comparison of the distribution of *T. inaurata* in 2008 and 2009

If we consider the spider distribution along the elevation, the results differ (Table II, Pearson's Chi-squared test p=0.027), mostly according to an increase of the density above the elevation of 600m in the year 2009. Although distribution of *T. inaurata* in 2008 (fig. 3) and 2009 (fig. 2) are similar, seven individuals have been recorded under the elevation of 500m while no *T. inaurata* had been recorded at this location the

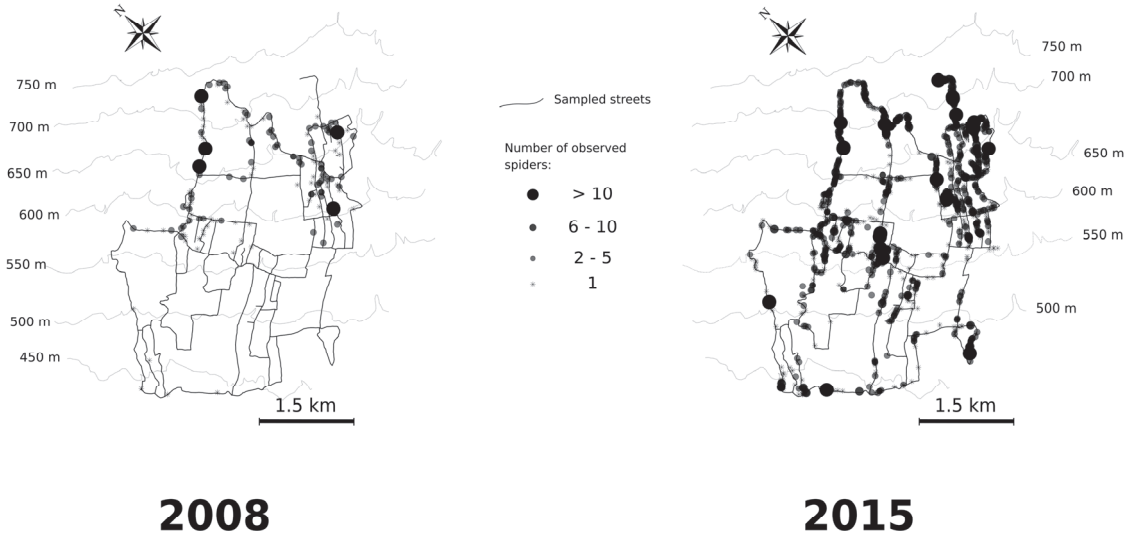


Fig. 3. *Trichonephila inaurata* distribution from 38.85 km of sampled streets in years 2008 and 2015.

year before. From 2008 to 2009, the spider density increases significantly (Student's t-test: p=0.0006).

Comparison of the distribution of *T. inaurata* in 2008 and 2015

Considering the years 2008 and 2015, both density and spatial distribution increased very significantly (Table III, fig. 3). In 2008, 654 *T. inaurata* individuals were counted in the 38.85 km considered. In 2015, on the same inventory track, 3,918 *T. inaurata* were counted (Table III), that means a very significant increase (Student's t-test: $p< 2.2\ 10^{-16}$). If we consider the spider density distribution along the elevation, results are highly different (Pearson's Chi-squared test: $p < 2\ 10^{-6}$) between the two years (fig. 3). Above the elevation of 550 m, there was a strong increase of spider density between 2008 and 2015. In the year 2015, below 550 m, where *T. inaurata* were almost absent in 2008, the whole space was recovered by the spider even if the density stayed lower than that observed above 550m.

Discussion

After the preventive ULV application in 2009 in two restricted areas, densities of *T. inaurata* were significantly lower than densities in control areas. In those areas, we didn't notice any local extinction despite deltamethrin spraying, as we did in 2007. In the current vector control strategy, the two ULV applications (day 0 and day +4) are not coupled with BMB application. On the one hand the amount of deltamethrin delivered is just 2g per ha versus 6g per ha with BMB applications. On the other hand, ULV application consisted in emitting a fog dispersed by wind from the street whereas BMB application was made from the garden and concentrated the insecticide on the vegetation, where spider webs are located. A lower amount of insecticide sprayed without targeting vegetation explains a lower impact of the new protocol on spider populations. The spiders located along the street are the most vulnerable whereas spiders located in the vegetation at a few metres from the streets are the most protected.

Despite ULV application in 2008 and 2009, distribution of *T. inaurata* in the year 2009 differs from the distribution in 2008. The difference remains in the colonisation of the lowest elevational areas by some individuals. This indicates a colonisation of *T. inaurata*-free areas by individuals which were dispersed from areas located in higher elevation at about two or three kilometres upstream. The best explanation of this medium-distance displacement is ballooning by spiderlings. In the study area, dominant winds are oriented North-East to South-West, in the same direction as the slope (Raunet, 1991). This hypothesis is also explained by the fact that the spiders located in the lower part of the study site were isolated.

In the study area, nine years after a local extinction, *T. inaurata* recolonised almost its entire original distribution area. This is due to the presence of a permanent population above 1000 m not impacted by vector control operation during the outbreak which occurred in 2006. The presence of the high elevation population and the high ability of this species to disperse are the key to the recovery. As a consequence, the geographical characteristics of the island where almost 50% of the surface is above 1000m are a fundamental element which allows the conservation of species with a great elevation range. A similar phenomenon occurred in a field experiment on two lizard species populations impacted by deltamethrin spraying: if there was a significant reduction in abundance of the two species following the spraying, 18 weeks after spraying there was no longer a significant difference in abundance measures between treatment and control plots, due to the invasion of the plots by juveniles (Alexander *et al.*, 2002).

If the major vector control operation did not impact the final seroprevalence rate in the human population of la Réunion comparatively to the neighbouring islands (Taglioni, 2010), its impact on *T. inaurata* density in urban areas conducted to a dramatic fall down. As the next outbreak caused by a mosquito or other insects is just a question of time, we call for an assessment of vector control efficiency and its impact on non target species. When an outbreak occurs, there is no time to evaluate the vector protocol impact on non target species with enough serenity. The main focuses are the number of sick people and actions carried out by authorities to control the situation. Our study shows the necessity of a long term monitoring of the fauna to detect the impact of use of insecticide or other anthropic disturbance on wild fauna even in urbanised areas. In absence of data, a decrease of

biodiversity could be not detectable in the early times and awareness may come too late to reverse the trend.

References

ALEXANDER, G.J., D. HORNE & S.A. HANRAHAN 2002. An evaluation of the effects of deltamethrin on two non-target lizard species in the Karoo, South Africa. *Journal of Arid Environments*, **50**(1): 121-133.

COUTEYEN, S. 2008. Impact sur *Nephila inaurata inaurata* (Walckenaer, 1842) (Araneae, Tetragnathidae, Nephilinae) de la lutte contre l'épidémie de Chikungunya à la Réunion. *Revue d'Ecologie,* **63**(3): 219-226.

DELATTE, H., C. PAUPY, J.S. DEHECQ, J. THIRIA & A.B. FAILLOUX 2008. *Aedes albopictus*, vecteur des virus du chikungunya et de la dengue à la Réunion: biologie et contrôle. *Parasite,* **15**(1): 3-13.

JOSSERAN, L., J.-L. SOLET, P. RENAULT, N. CAILLÈRE, A. FOUILLET, A. LE TERTRE, A. ZEGHNOUN, P. QUENEL, V. PIERRE, D. ILEF, M. LEDRANS & G. BRUCKER 2008. Description des fluctuations de la mortalité réunionnaise dans le contexte de l'épidémie de chikungunya en 2005-2006. *Bulletin Épidémiologique Hebdomadaire thématique*, **38-39-40**: 354-357.

KUNTNER, M. & I. AGNARSSON 2011. Phylogeography of a successful aerial disperser: the golden orb spider *Trichonephila* on Indian Ocean islands. *BMC Evolutionary Biology,* **11**(1): 119–119. https://doi.org/10.1186/1471-2148-11-119.

LAJOIE, G. & N. ACTIF 2001. Des villes jardins qui s'étalent depuis dix ans. *Economie de la Réunion,* **108**: 16-19.

RAUNET, M. 1991. *Le milieu physique et les sols de île de la Réunion, conséquences pour la mise en valeur agricole*. C.I.R.A.D.-I.R.A.T. Montpellier 438p.

SOUMAHORO, M.K., P.-Y. BOELLE, B.-A. GAÜZERE, K. ATSOU, C. PELAT, B. LAMBERT, G. LA RUCHE, M. GASTELLU-ETCHEGORRY, P. RENAULT, M. SARAZIN, Y. YAZDANPANAH, A. FLAHAULT, D. MALVY & T. HANSLIK 2011. The Chikungunya Epidemic on La Réunion Island in 2005–2006: A Cost-of-Illness Study. *PLoS Negleted Tropical Diseases,* **5**(6): e1197. doi:10.1371/journal.pntd.0001197.

TAGLIONI, F. 2010. Virus-sans-frontières : le chikungunya dans le sud-ouest de l'Océan Indien et au-delà. In : *Frontières et santé: genèses et maillages des réseaux transfrontaliers:* 249-266 (S. Duhamel, F. Moullé F.). Paris : L'Harmattan.