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Factores biogeográficos-sociales que determinan la distribución de *Triatoma recurva* en Chihuahua, México, 2014.

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Biogeographics factors that determine distribution of *Triatoma recurva* in Chihuahua, Mexico, 2014

Resumen del reporte técnico en español

Introducción: la enfermedad de Chagas es transmitida por triatominos que requieren de factores que son determinantes para su existencia y desarrollo biológico y que pueden influir en la transmisión de la tripanosomiasis a los seres humanos. Objetivo: Identificar una posible distribución espacial de Triatoma recurva y algunos factores sociales que determinan la presencia de este hemíptero. Materiales y métodos: El modelado de nicho ecológico se realizó a través de MaxEnt. Las variables bioclimáticas (WorldClim) utilizadas para este proceso se derivan de los valores mensuales de temperatura y precipitación para generar variables biológicamente significativas. La cartografía resultante se interpreta como áreas adecuadas para la presencia de T. recurva. Resultados: Los resultados muestran que la precipitación del mes (Bio 14), la temperatura máxima del mes más cálido (Bio 5), la altitud (Alt) y la temperatura media del trimestre más seco (Bio 9) determina en mayor porcentaje el área de distribución de estos triatominos. Se observa que T. recurva es una especie con una fuerte relación con las estructuras domésticas y circundantes. Conclusión: Esta metodología se puede utilizar en otros contextos geográficos para localizar posibles sitios de muestreo donde se encuentran estos triatominos.

Resumen del reporte técnico en inglés

Introduction: Chagas disease transmitted by triatomines requires factors that are determinant for their existence and biological development and that may influence the transmission of trypanosomiasis to humans. Objective: The objective of this study was to identify a potential spatial distribution of Triatoma recurva and some social factors that determine the presence of this hemipterus. Materials and Methods: The ecological niche modeling was performed through MaxEnt. The bioclimatic variables (WorldClim) used for this process are derived from the monthly values of temperature and precipitation to generate biologically significant variables. The resulting cartography is interpreted as suitable areas for hemipterus to be present. Results: The results show that the precipitation of the driest month (Bio 14), the maximum temperature of the warmest month (Bio 5), the altitude (Alt) and the mean temperature of the driest quarter (Bio 9) determine in a greater percentage the area of distribution of this triatomine. It is observed that T. recurva is a species with a strong relation to domestic and surrounding structures. Conclusion: This methodology can be used in other geographical contexts to locate potential sampling sites where these triatomines occur

Palabras clave: *spatial epidemiology, ecological niche model, bioclimatic variables, hematophagous vectors, hemiptera, maximum entropy*

Usuarios potenciales (del proyecto de investigación)

El sector de salud y epidemiología

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1. INTRODUCCIÓN

The Chagas disease or American Trypanosomiasis is a parasitic blood and tissue disease, caused by the flagellated protozoan Trypanosama cruzi, a haematophagous parasite located in tissue, especially the myocardial, which affected after a long evolutionary period (1, 2) causes irreversible heart diseases on 25% of the people. The transmission cycle of the Trypanosama cruzi constitutes a complex zoonosis which involves several vertebrate reservoirs and insects, the triatomine bugs, T.recurva, being chief among them (3, 4).

These insects belong to the Order Hemiptera, Infraorder Cimicomorpha, Superfamily Reduvioidae, Family Reduviidae, Subfamily Triatominae, which is comprised of more than 140 species grouped in 18 genera and five tribes. These five tribes show a great variability in the life cycles in their habitats where they live. Some authors indicate that some species of triatomine bugs have the ability of adapting to home environments and their peripheries, where they transmit T. cruzi to humans (5).

The Chagas disease is the most important parasitic disease in Latin America due to both its morbidity and its economic importance. This disease alone surpasses all the other parasitic diseases (6) and it is situated as the third most infectious important disease in Latin America, second only to AIDS and Tuberculosis.

In Mexico, this type of zoonosis derives from the population's social-economical level, which determines their access to resources, their hygiene practices and the quality of their housing, education and sanitation, especially potable water and drainage systems. (7, 8). T. recurva represents a risk factor for the population at large (9, 10). Nevertheless, access to information about this type of zoonosis in non-endemic places is insufficient as the disease is not considered a risk situation among the population. Thus, record-keeping of any related information is scant. In addition, it is difficult to gather epidemiological data regarding the death toll from the Chagas disease (11) due to lack of experience in clinical diagnosis, which also causes decision making in medical surveillance to be limited at best.

2. PLANTEAMIENTO

The distribution of Triatoma recurva and the presence of Trypanosama cruzi are determined by factors such as climate, rain, geographical barriers, humidity, topography, hosts, reservoirs and causal agents, all of which can also affect the ability of these hemiptera to transmit T. cruzi (12-14).

Acquiring knowledge of the spatial location of these factors and of the distribution of these hemiptera can be extremely useful to detect populations with vulnerability to diseases transmitted by these vectors.

Recently the systems of geographical information (SIG for its Spanish acronym) have been included in epidemiology to watch and monitor diseases transmitted by vectors (15-17); this is why geospatial analysis has become a useful tool for the development of proper intervention strategies.

One alternative to identify the biophysical variables that allow the presence of the taxonomic group is the Maximum Entropy algorithm known as MaxEnt (developed by Phillips and Dudik, 2008a) which combines statistics and Bayesian methodology to estimate distributions of maximum entropy subject to environmental information constraints (18).

The geographic distribution of Triatoma recurva is important for the study of its natural, ecological, genetic and evolutionary history as well as to obtain the information needed to understand the different biogeographic and historical factors conditioning the different diseases they transmit.

Knowing the distribution of Triatoma recurva could contribute to foresee a potential emergence or reemergence of diseases transmitted by the vector, along with helping to extend the current view of the distribution of this important group of insects in the country. Thus, the objective of this study was to identify the potential spatial distribution of Triatoma recurva factors that determine the presence of this hemipterus.

3. METODOLOGÍA

Area of Study

Chihuahua is located in the central part of northern Mexico (figure 1). On the north, it borders the states of New Mexico and Texas in United States of America; on the east it borders Coahuila de Zaragoza; on the south, the state Durango and on the east, the Sinaloa state. It's geographical coordinates are 25○30'and 31°47' north latitude and 103°18 to 109°07 west longitude. It is the biggest state of Mexico, stretching across 12% of the nation's surface with a total area of 247.45 km². Its climate is dry and semidry, and the annual average of rainfall is about 500 mm (19).

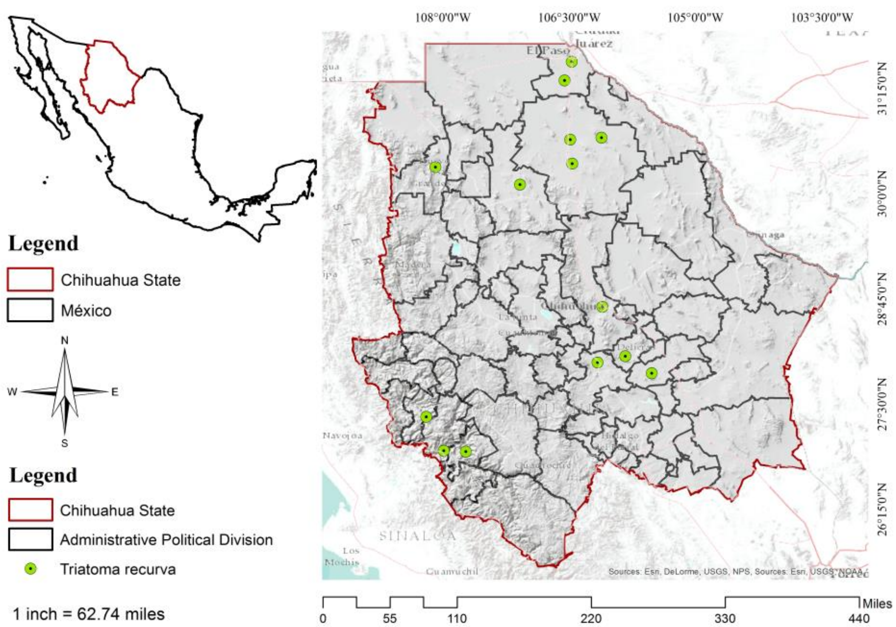

Figure 1. Area of study and presence of *Triatoma recurva*. Origin: Elaboration based in layers of CONABIO (20) and several sources of presence for *Triatoma recurva*. Figure prepared by the authors

Table 1. Environmental parameters for species distribution models WordClim (1950-2000), NDVI-MODIS 2014, topographic variables and land use variables.

Variables	Description
BIO1	Annual mean temperature
BIO2	Mean Diurnal Range **
BIO3	Isothermality
BIO4	Temperature seasonality
BIO5	Maximum temperature of warmest month **
BIO6	Minimum temperature of coldest month
BIO7	Temperature annual range **
BIO8	Mean temperature of wettest quarter (period of 3 months)
BIO9	Mean temperature of driest quarter (period of 3 months)**
BIO10	Mean temperature of warmest quarter (period of 3 months)
BIO11	Mean temperature of coldest quarter (period of 3 months)
BIO12	Annual precipitation
BIO13	Precipitation of wettest month
BIO14	Precipitation of driest month **
BIO15	Precipitation seasonality
BIO16	Precipitation of wettest quarter (period of 3 months)
BIO17	Precipitation of driest quarter (period of 3 months)
BIO18	Precipitation of warmest quarter (period of 3 months)
BIO19	Precipitation of coldest quarter (period of 3 months)
NDVI1	Normalized difference vegetation index to January 2014
NDVI2	Normalized difference vegetation index to February 2014
NDVI3	Normalized difference vegetation index to March 2014
NDVI4	Normalized difference vegetation index to April 2014
NDVI5	Normalized difference vegetation index to May 2014
NDVI6	Normalized difference vegetation index to June 2014
NDVI7	Normalized difference vegetation index to July 2014
NDVI8	Normalized difference vegetation index to August 2014
NDVI9	Normalized difference vegetation index to September 2014
NDVI10	Normalized difference vegetation index to October 2014
NDVI11	Normalized difference vegetation index to November 2014
NDVI12	Normalized difference vegetation index to December 2014
Alt	Altitude Z**
Acu	Accumulation of flux**
Pend	Slope
Asp	Situation of hillsides
Somb	Hillshade**
Uso	Soil use**

**Variables used for the model were obtained (not related among them) from Spearman statistical (< of 0.75, p = 95%, a = 0.025) and bootstrap of 1000 iterations.

Database and procedures

For the generation of the area of potential distribution of Triatoma recurva, 14 records of ocurrence were used, all of them located along the state of Chihuahua. The points of presence were obtained from the Global Biodiversity Information online website (1), Licón-Trillo (1) and from the Centro Nacional de Programas Preventivos y Control de Enfermedades (National Center for Preventive Programs and Disease Control) (12) (CENAPRECE, for its Spanish acronym) (20-23).

A group of biophysical variables was used from which 19 are climatological and 5 topographical derived from the MDE (hillshade), accumulation of flux, slope, hillside facings and altitude (Z) obtained from WorldClim (Table 1).

This database contains climate data that corresponds to global climate layers with a (homogenized) resolution of 1 Km obtained by cross-referencing weather station records (grids of 20 x 20 Km, ESRI format) from 1950 to 2000 coming from several sources at the global, national, regional and local levels. These layers feature bioclimate variables that are derived from the monthly temperature and the rainfall values in order to generate the most biologically significative variables (they represent annual tendencies and limiting factors for the species distribution) (20).

To complement this information, normal tables of contents of vegetation NDVI (Normalized Differenced Vegetation Index) were added, (21-23) which were generated by NASA by the MODIS sensor in the year 2014. These tables have a temporary monthly resolution and a spatial resolution of 1 Km2 (12 monthly NDVI variables by the 11th of each month) (modis. gsfc. nasa. gov/data-dataprod-mod13.php) as well as the land use variable generated by the INEGI for land use and the V 2015 vegetation series, which is available in vectorial format at a 1:250 000 scale in the geosite of the CONABIO with a total of 37 variables (24).

Adjustment of spatial resolution

Because the information collected was generated at different scales, it was necessary to standardize the scales based on the characteristics of the WorldClim variables (1 Km, because MaxEnt does not work at different scales) (columns, rows and pixel size) using ArcGis 10X, extract by mask module(25).

Selection of variables

The first step was to analyze the spatial correlation of the 37 predictor variables in the area of study. To that end, the Spearman correlation was calculated between pairs of variables dismissing whose correlation values exceeded $R \geq 0.75$ (since coefficients of 0.5 to 0.7 tend to be relevant in small samples). Spearman must be used for series of data in which there are extreme values, as calculations of the Pearson correlation will affect the results (26, 27).

In addition, a bootstrap resampling was made (1000 repetitions) where the independent covariables are expected to be present in the largest number of bootstrap samples, while noise variables are present as predictors in a lesser number of bootstrap samples (28).

The advantage of this resampling technique over the others is that if it is carried out automatically, it allows for the estimation of an empirical distribution function through the resampling of the observed data, and the selected model is not affected by autocorrelation (Table 1) (29).

The standard deviation was calculated with a confidentiality interval bias at 95% and a level of signification of $\alpha = 0.025$, using the IBM SPSS Statistics v20.0™ statistic software. From this process nine representative variables for the area of interest were obtained.

A Jackknife was run to eliminate negative contributions, so three variables were eliminated (Bio2, Somb and Uso).

Potential distribution

First, it was necessary to debug the database with occurrence records. Each point records information on its location: latitude and longitude on decimal degrees. The preparation of the environmental variables consisted of setting the type of format to ASCII, since MaxEnt only recognizes this format, and geospatially adjusting each variable to the area of study.

The MaxEnt algorithm was selected because its application in previous works has yielded good results (30, 31) even when data were scant (32) as in this case. Normally in MaxEnt the data is divided in two sets, one for the generation of the model and the other one for validation (33, 34).

However, with small size samples, this procedure is not suitable as important information is lost within the data set for validation (35). To solve this problem, a replication technique (bootstrapping) was used to generate 50 models. This way, random partitions of data are made in each replication, and each model is valued with a user defined percent (50% in this case). In bootstrapping, the sampling is done by replacement, which means that the records of presence can be used more than one time in the validation dataset for each replication (36-38).

The biophysics variables in this case are of the continuous type. In order to estimate which variables are more important to the model, a Jackknife test was done to discard the variables that did not contribute to it. After this, the test was performed again with the newly debugged data (39).

The logistic output was chosen to obtain those values that were easier to understand and processed later as they are used as a value of probability where these values fluctuate between 0 and 1, 0 showing incompatibility or absence of the species, and 1 showing suitability, or likelihood of the species presence (40).

The process of evaluation was conducted under the parameters established by Phillips et. al.(31). This process was made through the Characteristic Receiver's Operating Curve (ROC) calculating the area under the curve (AUC), which is obtained by comparing the proportion of false and true positives; simply put, to show in two axis, X and Y, the proportion of false positives (1-specificity) and on the Y axis the proportion of true positives (sensitivity) (41). The precision of the model is greater when the proportion of true positives is greater than that of the false positives. This can be expressed in a curve where the greater the precision the closer it will be to the left corner of the graphic, yielding a greater "curve area." The AUC with a value of 0.5 shows that the model has no predictive power, a value of 1 shows discrimination or a perfect model, and values below 0.5 show a much lesser relation than the one that was randomly expected (42, 43).

After the 50 models were generated, five maps from MaxEnt were selected; more specifically, those with greater percent of area under the curve, in order to incorporate them into the ESRI ArcGis software in its 10.2 version. Through map algebra, the average of such selection was calculated to obtain a consensus map and thus define the potentially sustainable areas for the species.

After this, a reclassification of the values was made based on the threshold established by MaxEnt: 10 percentile (which indicates the probability that 10% of the points of presence can lie out of the prediction area of the whole area of potential distribution) (44). Those probabilities under the threshold are transformed into 0 and are interpreted as absence of the hemiptera; those probabilities greater than the threshold are converted to 1and show the presence of the species.

4. RESULTADOS

The models were highly predictive of the distribution of Triatoma recurva based on random subsets. The AUC results and the highest percentages of contribution to the two-variable model by replication show the sustained importance of the variables (Table 2): Precipitation during the driest month , maximum temperature of the warmest month, Altitude (Alt), mean temperature of the driest quarter, all this indicates that the model's ability to classify presence was good, and that it can be considered acceptable and more precise than those of a randomly obtained model.

Table 2. Results of the area under the curve (AUC) and the highest percentage contribution of variables by reply.

Table 2. Results of the AUC and the highest percentage contribution of variables by reply

Number of Model	AUC	Variable of Importance	Percentage Contribution
17	0.8526	Precipitation of Driest Month	72.1
		Max Temperature of Warmest Month	27.9
16	0.8449	Max Temperature of Warmest Month	89.6
		Precipitation of Driest Month	10.4
26	0.8243	Max Temperature of Warmest Month	58.5
		Precipitation of Driest Month	41.5
40	0.8145	Precipitation of Driest Month	99.4
		Atitude	0.6
6	0.8136	Mean Temperature	100

of Driest Quarter

The resulting cartography was obtained through the replicas (6, 16, 17, 26, and 40) with AUC greater than 0.8 (Figure 2).

Table 2 shows the percentage contribution of the variables used to build the potential distribution model for Triatoma recurva: The mean temperature of the driest quarter (Bio 9) was the most important variable for the distribution of these hemiptera, with a contribution of 100%. Next, the highest temperature of the warmest month (Bio 5) followed by the precipitation of the driest month (Bio 14) with a 72.1%, and Altitude (Alt), 0.6%.

On the other hand, the Jackknife test indicates the variables that bring in more information to the model when isolatedly used; these were: Bio 5 (maximum temperature of the warmest month), Altitude (Alt), precipitation of the driest month (Bio 14), mean temperature of the driest quarter (Bio 9) and annual temperature range (Bio 7) (Figure 3).

The resulting cartography can be interpreted as suitable areas, which go from moderate to high, in the municipalities of: Batopilas, Urique, Morelos, Guachochi, Ascension and Ojinaga.

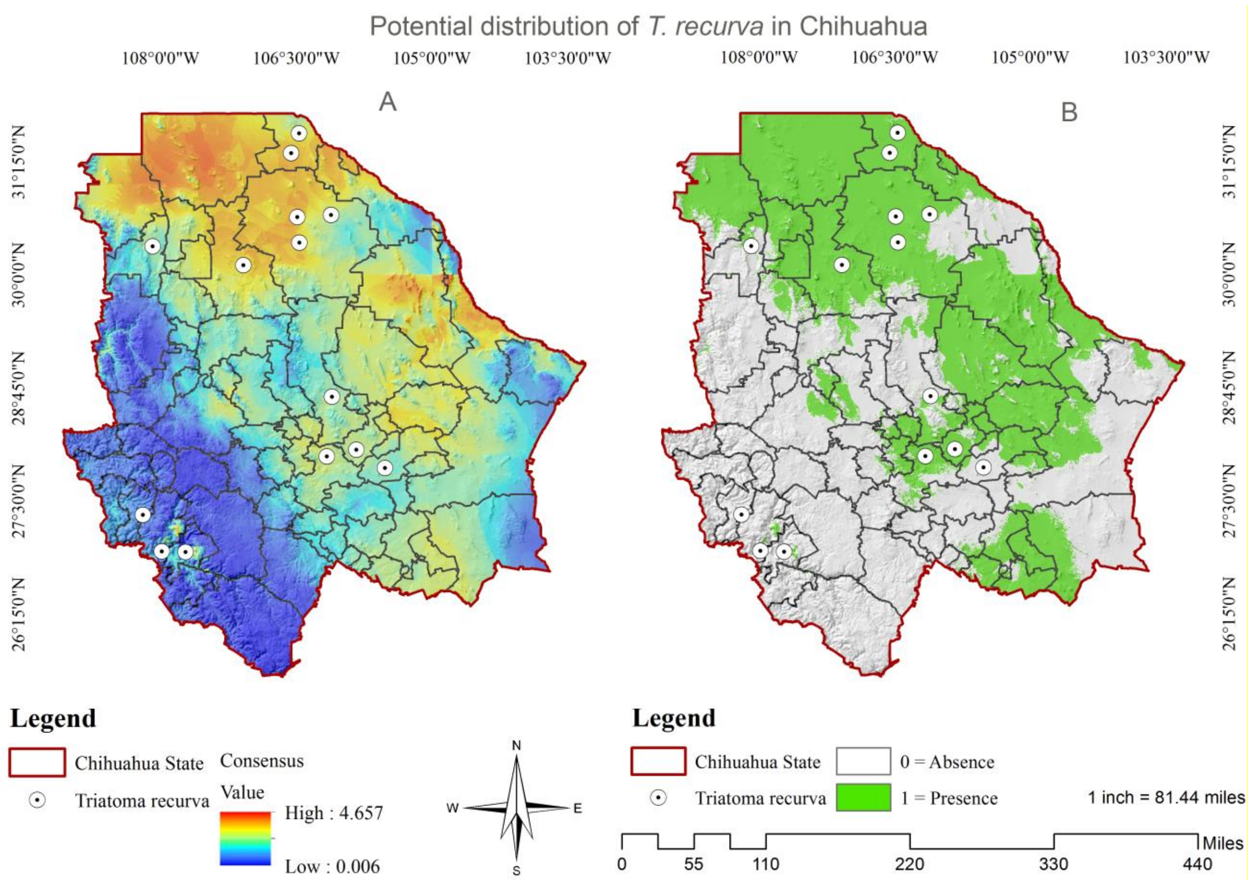

Figure 2. Consensus map (A): result of the addition of the five models with AUC < 0.8. Source: Individual elaboration based on the results obtained by the modeling in MaxEnt and algebra of maps. Map of

presence/absence (B) for the *Triatoma recurva* generated by the reclassification and algebra of maps. Source: Individual elaboration based on the results of MaxEnt, the reclassification by the percentile 100 and algebra of maps. Figures prepared by the authors

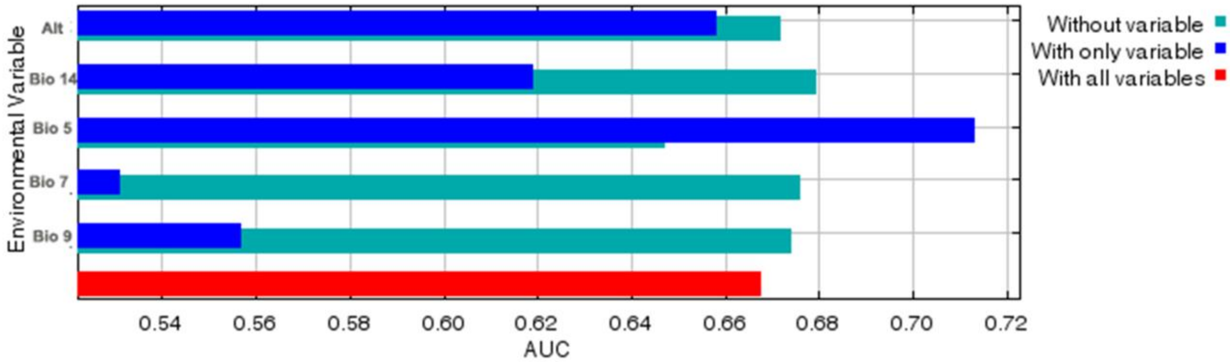

Figure 3. Jackknife Test of area under the curve (AUC) for *Triatoma recurva*. It shows the profit that each variable generates in three different sceneries: (a) running the model with only one variable (blue), (b) with all the variables except one (green), and with all the variables (red). This reflects how much useful information each variable contains. Figure prepared by the authors

5. CONCLUSIONES

The suggestion is that this type of investigations be considered basic information that may feed the nation's epidemiological surveillance system, placing special emphasis on the states of the country where the map of suitability has the highest values or where there are sub records showing the presence of these vectors. This methodology can be used in other geographical contexts to locate potential sampling sites where these triatomines occur

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ANEXOS

A. Se participó con una ponencia en el Congreso ANCA 2018 en Zacatecas

ANCA

ciencias de la tierra, u.a.z.

minas y metalurgia • geología • c. ambientales

La Academia Nacional de Ciencias Ambientales
y la Universidad Autónoma de Zacatecas
Francisco García Salinas
a través de
la Unidad Académica de Ciencias de la Tierra
y la Licenciatura en Ciencias Ambientales

Otorgan la presente

CONSTANCIA

A: ***María Elena Torres Olave, Gina Isabel Zesati Pereyra, Luis Carlos Alatorre Cejudo, Luis Carlos Bravo Peña, Mario Iván Uc Campos, Manuel Octavio González León, Lara Cecilia Wiebe Quintana, Alfredo Granados Olivas.***

Por: Su participación como Ponente con el trabajo: "**PROCESOS BIOGEOGRÁFICOS ENFOCADOS A VIGILANCIA EPIDEMIOLÓGICA DE Triatoma recurva EN CHIHUAHUA, MÉXICO.**" en el marco del XVII Congreso Internacional, XXVIII Congreso Nacional de Ciencias Ambientales, celebrado en la ciudad de Zacatecas, Zac., del 11 al 15 de junio de 2018

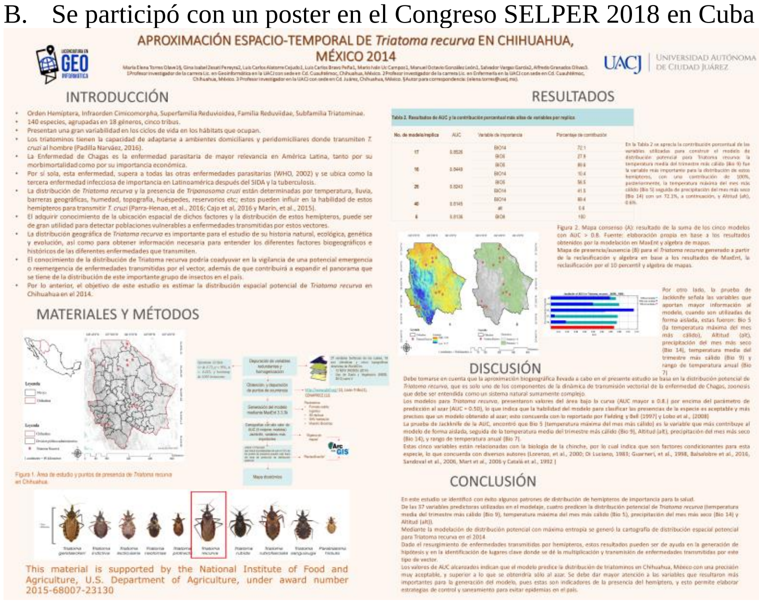
Zacatecas, Zac., 15 de junio 2018

Dr. Alberto Pereira Corona
Presidente ANCA

Dr. Santiago Valle Rodríguez
Secretario ANCA
Coordinador General Congreso 2018

XVII CONGRESO INTERNACIONAL
XXIII CONGRESO NACIONAL
DE CIENCIAS AMBIENTALES
ZACATECAS, ZAC., MÉXICO
11 - 15 junio 2018

B. Se participó con un poster en el Congreso SELPER 2018 en Cuba



SIMPOSIO INTERNACIONAL SELPER CUBA 2018

DESDE EL 6 AL 9 DE NOVIEMBRE DE 2018

HABANA VIEJA. CUBA

LAS NUEVAS TECNOLOGÍAS Y SU IMPACTO EN LAS INGENIERÍAS Y LAS GEOCIENCIAS

SE LE OTROGA EL PRESENTE

CERTIFICADO

A: María Elena Torres Olague

Gina Isabel Faseti Veleyra, Luis Carlos Alatorre Cejudo, Luis Carlos Bravo Peña, Mario Iván Uc Campos, Manuel Octavio González León, Salvador Vargas García, Alfredo Granados Olivas.

POR SU PARTICIPACIÓN COMO INVITADO

Dado en La Habana, Cuba.

Por haber presentado el poster Aproximación espacio-temporal de diarreas [illegible] en Chihuahua, México.

MSc. Pedro Luis García Pérez
Presidente del Comité Organizador

C. Se mandó un manuscrito a la Revista Biomédica
https://revistabiomedica.org/index.php/biomedica

Biomédica
Revista del Instituto Nacional de Salud

Volumen 39

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Bogotá D.C., 13 de junio de 2019

Doctora
María Elena Torres
Unidad Multidisciplinaria
Universidad Autónoma de Ciudad Juárez
Cuauhtémoc, Chihuahua, México

Ref. Manuscrito 86 19 "Biogeographics and socials factors that determine the distribution of Triatoma recurva in Chihuahua, Mexico, 2014"

Doctora Torres:

Con la presente nos permitimos acusar recibo del manuscrito de la referencia, para consideración de la revista *Biomédica* del Instituto Nacional de Salud.

Para cualquier información, el número de registro del manuscrito es 86 19.

Agradecemos a ustedes considerar a *Biomédica* para la publicación de su manuscrito.

Cordial saludo,

Comité Editorial *Biomédica*

**Nota: El reporte técnico tendrá una extensión mínima de 5 cuartillas y máxima de 30, a espacio y medio.
CONSIDERACIONES:

- Los reportes deben estar escritos en español o en inglés.
- Se debe entregar en formato Word acorde a este formato.
- El texto debe ser escrito en hoja tamaño carta a espacio y medio, y los márgenes deberán encontrase al menos a una pulgada (2.54 cm). La totalidad del texto debe escribirse en minúsculas, utilizando las mayúsculas sólo al principio de las oraciones y para los títulos de capítulos.
- Se recomienda usar el tipo de letra Arial tamaño 10, o Times new Roman tamaño 12.
- Todas las páginas deben estar numeradas en secuencia comenzando desde la portada.
- La extensión total del texto es de un mínimo de 5 cuartillas y un máximo de 30 cuartillas, con un interlineado de espacio y medio.

- Archivos de Excel de tablas y gráficas deben ser adjuntados al reporte enviado electrónicamente.
- Las figuras, fotografías y tablas, serán insertadas en el cuerpo del texto y numeradas en forma consecutiva comenzando con 1 y de manera independiente de las tablas. El número y descripción de la figura, tabla, etc., deberá colocarse antes de la misma.
- Se recomienda evitar el uso de sombras y líneas punteadas que no permitan una legibilidad clara de imágenes.
- Las fórmulas y ecuaciones deben hacerse con un editor de ecuaciones como el que viene en Word. Estarán centradas y separadas del texto. La numeración será consecutiva comenzando con 1. El número de la fórmula deberá encerrarse entre paréntesis y colocarse a la derecha de la fórmula lo más cercano posible al margen derecho.
- Las referencias bibliográficas en el texto deben ser en cualquier estilo reconocido como APA, MLA, ISO, etc.
- Los anexos se colocarán al final del documento después de la bibliografía, utilizando caracteres alfabéticos para distinguirlos: Anexo A, Anexo B, etc. La información contenida en los anexos es importante pero no indispensable para la comprensión del trabajo. Se recomienda colocar en los anexos mapas, fotografías, tablas, desarrollos matemáticos, diagramas, etc.