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INSECT VECTORS AND THEIR RELATIONSHIP WITH SUSTAINABLE DEVELOPMENT INDICATORS IN NEIGHBORHOODS OF NATAL, NORTHEASTERN BRAZIL

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ABSTRACT – This study aimed to correlate sustainable development indicators with the occurrence of mosquitoes from the genus *Aedes* and phlebotominae sand flies, vectors of dengue fever, American visceral leishmaniasis and American tegumentary leishmaniasis, in order to establish a relationship between infestation indices and sustainability conditions in southern and northern neighborhoods of Natal, Brazil, adjacent to environmental protection zones 5 and 9, respectively. Data were obtained on *Aedes aegypti* and *A. albopictus* breeding sites and captures of phlebotominae sand flies of the genus *Lutzomyia* in the study area between 2006 and 2008, from the Center of Zoonosis Control of the Municipal Health Secretariat, and correlated with environmental and social indicators. Factorial analysis was applied to transform these indicators into a sustainability index for each neighborhood studied (Neighborhood Sustainability Index – NSI). Relating these indices with the occurrence of insect vectors at these sites shows a high positive correlation between SID and the Breteau index of *A. aegypti* ($p=0.028$) and with the index of household infestation by phlebotominae sand flies ($p=0.01$). This reveals a pattern allowing the association of sustainability conditions in the study areas with the occurrence of these insects. Analyses demonstrate the occurrence of a larger number of *A. aegypti* breeding sites and higher indices of household infestation by phlebotominae sand flies in neighborhoods with lower sustainability indices. Knowledge of the relationship between sustainable development indicators and the occurrence of zoonotic vectors may contribute to public health programs as well as to a restructuring of public policies in the study areas.

KEY WORDS: SUSTAINABILITY, ENVIRONMENT, URBANISM, VECTOR INSECTS, DENGUE FEVER, LEISHMANIASIS.

INSETOS VETORES E SUA RELAÇÃO COM INDICADORES DE DESENVOLVIMENTO SUSTENTÁVEL EM BAIROS DE NATAL, NORDESTE DO BRASIL

RESUMO – Neste estudo procurou-se correlacionar indicadores de desenvolvimento sustentável listados na publicação “Indicadores de Desenvolvimento Sustentável – Brasil 2008” (IDS-Brasil 2008) com a ocorrência de mosquitos do gênero *Aedes* e flebotomíneos vetores de Leishmaniose Visceral Americana e Leishmaniose Tegumentar Americana, de forma a estabelecer uma relação entre os índices de infestação encontrados e a situação de sustentabilidade de bairros da zona sul e zona norte do município de Natal, adjacentes, respectivamente, às Zonas de Proteção Ambiental 5 e 9. Os dados sobre a ocorrência de criadouros de *Aedes aegypti* e *A. albopictus* e de capturas de flebotomíneos do gênero *Lutzomyia* na área de estudo durante o período de 2006 a 2008 foram obtidos junto à Secretaria Municipal de Saúde, através do Centro de Controle de Zoonoses, e correlacionados a indicadores ambientais e sociais. Através de Análise Fatorial, estes indicadores foram transformados num índice de sustentabilidade atribuído a cada um dos bairros estudados (Índice de Sustentabilidade do Bairro – ISB). Relacionando estes índices com a ocorrência de insetos vetores nestes locais, observou-se alta correlação positiva entre o ISB e o Índice de Breteau de *A. aegypti* ($p=0,028$) e com o índice de infestação domiciliar por flebotomíneos ($p=0,01$), revelando um padrão que permite associar as condições de sustentabilidade das áreas estudadas com a ocorrência destes insetos. As análises demonstram a ocorrência de maior número de criadouros de *A. aegypti* e de Índices de Infestação Domiciliar por flebotomíneos mais altos em bairros com Índices de Sustentabilidade piores. O conhecimento da relação entre Indicadores de Desenvolvimento Sustentável e a ocorrência de vetores de zoonoses poderá contribuir com os programas de saúde pública e com uma redefinição das políticas públicas nas áreas estudadas.

PALAVRAS-CHAVE: SUSTENTABILIDADE, DESENVOLVIMENTO, MEIO AMBIENTE, URBANISMO, INSETOS, VETORES, DENGUE, LEISHMANIOSE.

INSETOS VETORES Y SU RELACIÓN CON INDICADORES DE DESARROLLO SOSTENIBLE EN BAIROS DE NATAL, NORDESTE DO BRASIL

RESUMEN – This study aimed to correlate sustainable development indicators with the occurrence of mosquitoes from the genus *Aedes* and phlebotominae sand flies, vectors of dengue fever, American visceral leishmaniasis and American tegumentary leishmaniasis, in order to establish a relationship between infestation indices and sustainability conditions in southern and

northern neighborhoods of Natal, Brazil, adjacent to environmental protection zones 5 and 9, respectively. Data were obtained on *Aedes aegypti* and *A. albopictus* breeding sites and captures of phlebotominae sand flies of the genus *Lutzomyia* in the study area between 2006 and 2008, from the Center of Zoonosis Control of the Municipal Health Secretariat, and correlated with environmental and social indicators. Factorial analysis was applied to transform these indicators into a sustainability index for each neighborhood studied (Neighborhood Sustainability Index – NSI). Relating these indices with the occurrence of insect vectors at these sites shows a high positive correlation between SID and the Breteau index of *A. aegypti* ($p=0.028$) and with the index of household infestation by phlebotominae sand flies ($p=0.01$). This reveals a pattern allowing the association of sustainability conditions in the study areas with the occurrence of these insects. Analyses demonstrate the occurrence of a larger number of *A. aegypti* breeding sites and higher indices of household infestation by phlebotominae sand flies in neighborhoods with lower sustainability indices. Knowledge of the relationship between sustainable development indicators and the occurrence of zoonotic vectors may contribute to public health programs as well as to a restructuring of public policies in the study areas.

PALABRAS CLAVE: SOSTENIBILIDAD, DESARROLLO, MEDIO AMBIENTE, PLANIFICACIÓN URBANA, INSECTOS, VECTORES, DENGUE, LEISHMANIASIS.

INTRODUCTION

Rural-urban migration, caused primarily by the search for better economic conditions, is an important social problem in that municipal administrations have been unable to provide comprehensive services such as safe drinking water, sanitary sewer systems, and trash collection, creating environmental degradation that favors the emergence or increased occurrence of insect-transmitted diseases (Bos 1992). The expansion of some insect-transmitted zoonotic disorders is also related to the social-environmental context and intra-urban differences, which may favor vector survival, despite the control measures implemented (Oliveira et al. 2008).

The high urbanization index in Brazil, with more than 80% of inhabitants living in cities, in addition to its rapid and haphazard occurrence, led to a condition in which around 20% of urban dwellers settled in areas lacking basic infrastructure (Tauil 2006).

In 1981, most cases of the visceral leishmaniasis epidemic in Teresina, Piauí, originated in new neighborhoods and migrant settlements, reaching established urban areas one year later (Costa et al. 1990). In the greater metropolitan region of Belo Horizonte, in Southeast Brazil, the presence of animals and areas in rural-urban transition were considered factors associated with the rise in cases of human visceral leishmaniasis (Oliveira et al. 2008).

Dengue fever is transmitted through *Aedes* mosquito bites and its recrudescence is due to reinfestation by *Aedes aegypti* (Forattini e Brito 2003), (Gubler 1997). *Aedes albopictus*, despite its preference for forest environments, is also considered a vector of the disease and responsible for the 2001-2002 dengue fever epidemic in Hawaii (CDC, 2008). Its presence should lead to the immediate implementation of control programs, since it is also a transmitter of the yellow fever virus.

The campaign to control *A. aegypti* is the largest ongoing public health initiative in the country. It concentrates on the only weak link in the transmission cycle, that is, the vector, in an attempt at eliminating breeding sites. However, success depends on an efficient sanitary structure, consisting of indoor plumbing, regular trash collection and improved living conditions, in addition to an informed population (Tauil 2006). Furthermore, this mosquito transmits urban yellow fever, which, in Brazil, is still concentrated in forest areas, causing epizootic diseases in monkeys and individuals who venture into these areas.

Dengue fever occurs in all Brazilian states and in 3794 municipalities, accounting for around 60% of notified cases in the Americas. It typically emerges in the hotter months, with

significant quantitative differences among regions, the Northeast and Southeast recording the largest number of cases (Câmara et al. 2007).

The existence of four antigenically distinct serotypes favors its dissemination and hinders its control, since infection by one of the serotypes promotes specific immunity, leaving the individual susceptible to new infections (Cordeiro et al. 2007). The disease is considered to be related to poor environmental sanitation.

Dengue fever cases have been reported in Rio Grande do Norte state since 1996. Since then, there have been outbreaks of the disease in alternate years, with a peak of 19,221 cases in 2001 (SMS, 2008).

The etiological agent of American visceral leishmaniasis (AVL) is *Leishmania (L.) infantum chagasi* Nicolle (Kinetoplastida: Trypanosomatidae) and its vector is *Lutzomyia longipalpis* Lutz & Neiva (Diptera: Psychodidae). Until the mid-1970s it was considered a typically rural zoonotic disease (Taulil 2006), (Caiaffa et al. 2005). Since then, this disorder, together with American tegumentary leishmaniasis (ATL) has significantly increased in the urban and peri-urban areas of several Brazilian cities, mainly in the Northeast.

Although the presence of domestic and wild animals is associated to an increase in the occurrence of *L. longipalpis* (Ximenes et al. 1999), proximity to forest areas and socio-environmental factors such as inadequate trash collection, low nutritional index and lack of basic sanitation are relevant aspects to consider in AVL and ATL control.

In the previously mentioned 1981 AVL epidemic in the state of Piauí, Northeastern Brazil, the emergence of cases was related to the drought that afflicted the states of Ceará and Piauí between 1978 and 1983, when large numbers of people migrated to the state capital, forming precarious peripheral settlements. These migrant groups, naturally more susceptible to disease owing to their low nutritional index, came from areas endemic for *L. chagasi*, establishing their role in introducing the parasite into the metropolitan area of Teresina (Costa et al. 1990).

The problem, therefore, is related to environmental quality and socio-environmental factors in the areas analyzed, where there must be suitable sites for the vector insect to breed. Variables such as trash collection, water supply, and sanitary sewer systems favor the occurrence of these insects. Access to these services is often related to the socio-economic level of the area in question. It is also considered that lack of infrastructure is an important vulnerability factor when investigating the health of inhabitants of a particular region (Ompad et al. 2007). The present study used sustainable development indicators to parametrize these factors and relate them to the occurrence of zoonotic vectors.

Sustainability indicators help to understand conditions which may trigger important public health problems. However, indicators are often not capable of accurately defining the degree of environmental degradation or unsustainability. Nevertheless, when social, environmental and economic parameters are correlated they become important tools to help formulate public policies in order to provoke social organization and a political response to certain issues (Tayra e Ribeiro, 2006).

The role of administrations in promoting and managing public health policies, and the strengthening of these policies by using sustainable development indicators as a reference, is a central factor in adjusting the planned trajectory towards sustainability. Successful municipal government initiatives demonstrate that policies and programs based on environmental

sustainability principles result in economic and social benefits (Bos, 1992), (Vlahov et al. 2007), (Malheiros et al 2008).

According to Vlahov (Vlahov et al. 2007) and Kjellstrom (Kjellstrom et al. 2007), demographic, physical and social factors, such as age and gender, access to indoor plumbing and a sanitary sewer system, rainfall drainage, trash collection and income are relevant factors with respect to the overall health of a population.

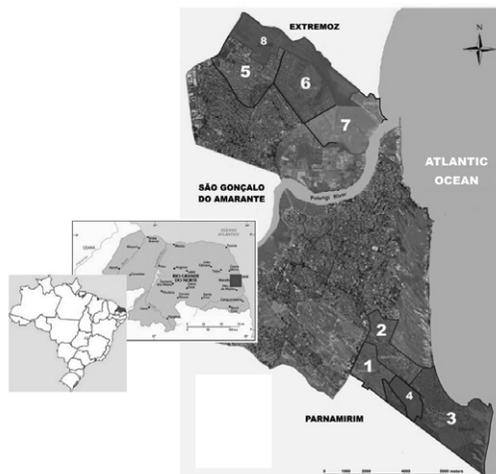
Knowledge of the relationship between sustainable development indicators and the occurrence of disease vectors may contribute to public health programs and a possible restructuring of public policies in the study areas. Thus, the present study aimed to establish a relationship between sustainable development indicators and the occurrence of dengue fever, AVL and ATL vectors in southern and northern neighborhoods of Natal.

MATERIALS AND METHODS

Study area

The study was conducted in the city of Natal, located in the homogeneous zone of the eastern coast of Rio Grande do Norte (05°47'42" S and 35°12'34" W) in neighborhoods of the Southern and Northern regions. The former consists of Capim Macio, Ponta Negra and Neopolis and is adjacent to the environmental protection zone denominated EPZ (Environmental Protection Zone) -5/Association of Dunes and Lakes of Ponta Negra – Lagoinha. Neighborhoods studied in the latter were Lagoa Azul, Pajuçara and Redinha, adjacent to EPZ-9/Lake Complex and Dunes along the Doce River.

Figure 1 - Study Area. Legend: 1 – Neopolis; 2 - Capim Macio; 3 - Ponta Negra; 4 – EPZ 5; 5 – Lagoa Azul; 6 – Pajuçara; 7 – Redinha; 8 – EPZ 9. Adapted from Almanac of Natal for 2009



Physical and urban characterization of the study area

Physical data (area, population, demographic density, trash collection, indoor plumbing and/or a sanitary sewage system, literacy rate and per capita income) of the study regions were obtained from the Almanac of Natal for 2006, 2007 and 2009, with the last published in 2009 containing data from 2008 (Semurb 2006), (Semurb 2007), (Semurb 2009). Occupation and urban densification within the EPZs was measured by AutoCAD 2010 software, using satellite images provided by the Municipal Secretariat for the Environment and Urbanism.

Land can be legally occupied at the outer perimeter of the EPZs and, in some cases, through complementary legislation, towards the center. A significant rise in construction has been observed due to the ever-increasing value of land in the vicinity of these areas. Furthermore, it is known that migrants from rural regions tend to occupy non-urbanized areas lacking in infrastructure, notably near native forests. Thus, in less valued regions of the municipality there is increased occupation around the EPZs, primarily by individuals migrating from rural areas of the state (Oliveira et al. 2004).

Even with the adoption of municipal control measures, the proximity of native forests also provides natural habitats for insect vectors, allowing an undesirable interaction with the surrounding population (Barbosa et al. 1993), (Forattini et al. 1998), (Medeiros et al. 2009), in a study in EPZ-2 (Natal Dunes State Park), collected specimens of *Aedes albopictus* and *Haemagogus leucocelaenus* in a native forest near a densely urbanized area. Both are arbovirus vectors and *H. leucocelaenus* was recently found infected by the yellow fever virus in the south of the country.

The existence of insect vectors in the EPZs and the proximity of residences may contribute to the increased incidence of zoonotic diseases such as dengue fever (Gubler 1997), (Forattini et al. 1998), (Chiaravalloti Neto et al. 2002), American visceral leishmaniasis (AVL), American tegumentary leishmaniasis (ATL) and yellow fever (Medeiros et al. 2009), resulting in altered endemic or epidemic levels of these diseases (Patz et al. 2000), (Cabrera et al. 2003), (Ximenes et al. 2007).

Occurrence of vector insects in the study areas

Data on the occurrence of breeding sites for *Aedes aegypti*, *Aedes albopictus* and phlebotominae sand flies found in dwellings adjacent to EPZ-5 (neighborhoods of Ponta Negra, Neopolis and Capim Macio) and EPZ-9 (neighborhoods of Redinha, Pajuçara and Lagoa Nova) were obtained from the Municipal Health Secretariat (MHS) and the Center for Zoonotic Control (CZC). Due to the collection method used by the CZC, the neighborhoods of Capim Macio and Neopolis were grouped.

The occurrence of aedine breeding sites was calculated based on the *Aedes aegypti* Infestation Index Rapid Survey (LIRAA), conducted in Natal between 2006 and 2008. Positive cases were grouped according to predial infestation indices and the Breteau Index (number of receptacles inhabited by immature forms of mosquitoes in relation to the number of dwellings examined to identify breeding sites) (Silva et al. 2006). The Breteau index was selected for statistical analysis since it is more sensitive in detecting mosquito positivity (Braga et al. 2000).

Data on the occurrence of phlebotominae sand flies were obtained from entomological

collections performed monthly by the CZC in the neighborhoods of Redinha, Pajuçara and Lagoa Azul, from 2006 to 2008, using CDC traps set between 18:00 and 6:00h, in groups ranging from 7 to 10 residences. Specimens were counted, identified and classified according to capture sites. The household infestation index, defined as the ratio between positive dwellings and the total number investigated, was then calculated (Silva et al. 2006).

Sustainable development Indicators

Sustainable development indicators are grouped according to the framework proposed by the Sustainable Development Commission (SDC) of the United Nations, which is organized into four dimensions: Environmental, Social, Economic and Institutional. Relevant indicators were selected and adapted to the study regions (neighborhoods adjacent to EPZs 5 and 9) in the Environmental (access to trash collection, indoor plumbing and sanitary sewer systems) and Social domains (per capita household income and literacy rate), based on IDS-Brasil 2008 (Sustainable Development Indicators), with data available in the Natal Almanac of 2006, 2007 and 2009 (Municipal Secretariat of the Environment and Urbanism - Semurb).

A cross-section was performed of sustainable development indicators listed in IDS-Brasil 2008 related to indicator 36 (Diseases Related to Inadequate Environmental Sanitation). Indicators were selected from the environmental (access to trash collection, indoor plumbing and sanitary sewer systems) and social dimensions (per capita household income and literacy rate). This cross-section is justified by the fact that the zoonotic diseases studied here “may be associated to inadequate drinking water, unsuitable sanitary sewer systems, solid waste contamination or precarious living conditions” (IBGE 2008).

In the environmental dimension, *Access to trash collection* (IDS-Brasil 2008 - Indicator 19) “identifies the portion of the population with trash collection services in a given territory and time period”. It consists of the ratio (%) between individuals receiving these services and the total population. This indicator may be associated to the health of the population, since uncollected or inadequately disposed waste might favor the proliferation of disease vectors.

Access to indoor plumbing (IDS-Brasil 2008 - Indicator 21), “represents the portion of the population with access to indoor plumbing” and consists of the ratio (%) between those with indoor plumbing and the total population with permanent housing. It is an important indicator for characterizing quality of life, enabling the monitoring of environmental and basic sanitation policies. When associated with environmental and socioeconomic information such as sanitation and income, it is a universal indicator of sustainable development.

Access to a sanitary sewer system (IDS-Brasil 2008 - Indicator 22), “exhibits the ratio between the population served by the sanitary sewer system and those living in permanent residences in a given territory”. The indicator is the ratio (%) between the population with access to a sanitary sewer system (by a sewer network or septic tank) and the total population.

In the social dimension, *Per capita household income* shows the percentage of families by mean per capita monthly income (MMI). Variables used are the total number of resident families and per capita household income discriminated by income classes according to the number of minimum monthly wages.

Literacy rate represents the literate population aged 5 years or older.

Indicator values for the study years (2006 to 2008) were transformed into mean values for statistical analysis.

Factorial Analysis – Elaboration of the Neighborhood Sustainability Index

A factorial analysis of the neighborhoods was carried out, using the principal components and maximum likelihood methods, to determine the number of factors. Johnson (Johnson and Dean 2007) recommends using both methods to verify if the two different methodologies result in the same factors. STATISTICA® 7.0 software was used for calculations.

This analysis revealed the number of a factor, with the principal component method explaining 87.6% of total variance. Once vector data corresponding to factorial scores are obtained, this column is multiplied by the respective estimate of the variance of the factor, in this case given by the corresponding eigenvalue of the sample correlation matrix. The column was arranged in ascending order and used to define indices, creating a sustainability index for each of the neighborhoods studied. These were then separated into two strata: low and high.

Pearson's linear correlation coefficient with a significance level less than or equal to 5% ($p \leq 0.05$) was used for correlation analysis.

RESULTS AND DISCUSSION

a) Physical and urban characterization of the study area

EPZs 5 and 9 exhibit different physical characteristics. EPZ-5 occupies an area of around 193 ha, is located at the southernmost limit of Natal, bordering Parnamirim, regulated by complementary legislation and surrounded by wealthier neighborhoods. On the other hand, EPZ-9 is situated in the northernmost part of Natal, on the border with Extremoz. It encompasses an area of about 734 ha, is not regulated and adjacent neighborhoods are inhabited by economically less privileged individuals (Semurb, 2009).

EPZ-5 is located in a densely urbanized area, with a predominance of residential dwellings. The inner portion is relatively well preserved (88.8%), with approximately 4% of the area occupied by scattered residences and about 7.2% of the protected area by a gated community. However, surrounding this EPZ are the neighborhoods of Capim Macio (438 ha), Neópolis (408 ha) and Ponta Negra (707 ha), all highly urbanized (Semurb, 2009).

A total of 20.2% of EPZ-9 within the municipality of Natal is occupied by residential dwellings and approximately 15.5% by small farms, leaving 64.3% of the area preserved. The adjacent area lying within Natal is totally urbanized, divided among the neighborhoods of Lagoa Azul, with 1043 ha, Pajuçara, with 776 ha and Redinha, with 787 ha (Semurb, 2009).

Mean demographic density for the years under study is similar in the two regions, with 47.69 and 46.79 inhabitants per hectare in the Southern and Northern Regions, respectively.

b) Indicators for the neighborhood sustainability index

Results show better sustainable development indicators in neighborhoods located near

EPZ-5 (South Zone), while worse indicators were observed in neighborhoods surrounding EPZ-9 (North Zone) (Table 1). Although all the neighborhoods studied were situated near the environmental protection zones, a situation that may favor the occurrence of zoonotic diseases such as dengue fever or leishmaniasis, their urban and socio-demographic characteristics could also affect the number of cases.

Table 1 – Sustainable Development Indicators by neighborhood – mean between 2006 and 2008.

EPZ	Neighborhoods	SUSTAINABLE DEVELOPMENT INDICATORS				
		% of dwellings with trash	% of dwellings with indoor plumbing	% de dwellings with sanitary sewer systems	Literacy rate (%)	Per capita income (in minimum monthly wages)*
EPZ-5	Ponta Negra	98	89	86	90	9.43
	Capim Macio/Neópolis	99	97	96	97	11.89
EPZ-9	Redinha	94	77	53	74	2.60
	Pajuçara	96	79	77	84	2.82
	Lagoa Azul	97	82	68	81	2.35

In the environmental dimension, *Access to trash collection* showed a non-significant variation among the neighborhoods studied, with 98.8% of the population served in Capim Macio/Neópolis as the best result and 93.5% in Redinha as the most unfavorable outcome.

In *Access to indoor plumbing* Redinha obtained the worst result in terms of water supply, with only 77% of households connected to the public network, whereas in Capim Macio/Neópolis 97% of homes had indoor plumbing.

The *Access to a sanitary sewer system* displayed the same tendency as previous ones, with Redinha once again showing the worst results (53% served), while 96% of households in Capim Macio/Neópolis had access.

Capim Macio/Neópolis obtained the best results in *Per capita household income*, with MMI of 11.89 minimum monthly wages versus 2.35 in Lagoa Azul.

In *Literacy rate*, Capim Macio/Neópolis maintained the previously described pattern, obtaining the highest value in this indicator (97%), with Redinha showing the worst indicator (74%).

c) Sustainability Index

Table 2 shows that both trash and income are significantly correlated to the variables water, sewer system and literacy.

Thus, the variables Trash and Income, whose correlation is not statistically significant, were selected to build the neighborhood sustainability index.

The principal components and maximum likelihood methods were used to determine the number of factors. In other words, the same selection of factors is obtained by both methods when their number is equal to one. The principal components method explains 87.6% of total variance, while maximum likelihood explains 75.2%.

The median of indexes is determined from the defining column, allowing the division of neighborhoods into two groups. These groups were hierarchized into Neighborhood Sustainability Indexes (NSI) by strata, and classified as low (indices \leq median) and high (indices $>$ median).

The use of indicators enables an understanding of the complexity of the system, without reducing the importance of each of its components, contributing to the implementation of development models that promote environmental and social development policies for significant portions of the population.

Table 2 – Correlation matrix of Sustainable Development Indicators.

Variables	Trash	Water	Sewer	Literacy	Income
Trash					
Water	0.894 p=0.041				
Sewer	0.8857 p=0.046	0.9002 p=0.037			
Literacy	0.8962 p=0.040	0.9483 p=0.014	0.9908 p=0.001		
Income	0.752 p=0.143	0.9547 p=0.011	0.8595 p=0.062	0.9067 p=0.034	

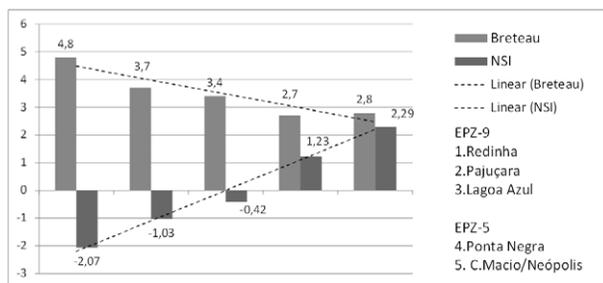
d) Analysis of Aedes aegypti occurrence using the Breteau Index

Analysis of the Breteau Index and the Neighborhood Sustainability Index (NSI) shows a significant negative correlation of -0.92 (p=0.028), thereby establishing a relationship between the former index and the strata studied.

Comparison of the data obtained reveals an association between environmental and socioeconomic conditions of the study areas, according to IDS-Brasil 2008, adapted to the neighborhoods selected, and the Breteau Index, which in turn determines the infestation of these neighborhoods by *A. aegypti*.

Therefore, it can be concluded that neighborhoods with worse indicators show a tendency to contain a larger number of *A. aegypti* breeding sites. Thus, neighborhoods with worse sanitary sewer systems, less access to trash collection and internal plumbing, as well as lower household per capita income would be more susceptible to the occurrence of this vector.

Figure 2 - Analysis of the Breteau Index tendency for *A. aegypti* in relation to the Neighborhood Sustainability Index (NSI).



e) Occurrence of *Aedes albopictus* using the Breteau Index

Although proximity to an area of native forest, as is the case for the environmental protection zones, favors the presence of insect vectors such as *Aedes albopictus*, no significant occurrence of breeding sites was observed in urban and peri-urban environments of the study areas. The small number of positive cases (Breteau Index ≤ 0.2) did not allow statistical analysis in relation to the sustainability index obtained.

f) Analysis of the occurrence of phlebotominae sand flies using the Household Infestation Index

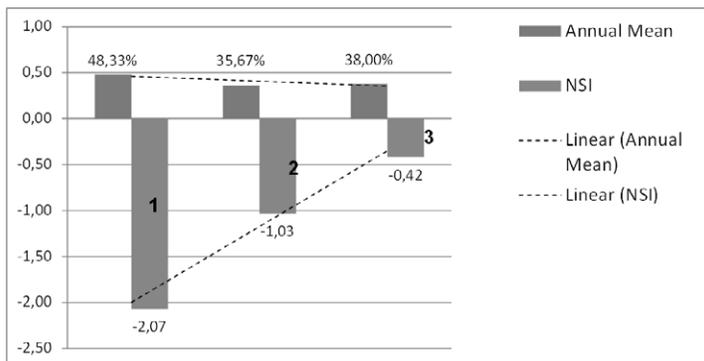
Occurrence of phlebotominae sand flies in the study areas was analyzed based on the household infestation index, expressed by the ratio between number of households with positive captures and the total number investigated. Due to the non-existence of data in the CZC with respect to sand fly captures in neighborhoods adjacent to EPZ-5, only captures performed in the neighborhoods of Redinha, Pajuçara and Lagoa Azul were considered in this analysis.

The correlation matrix between the household infestation index and the neighborhood sustainability index reveals a negative significant correlation between these variables, with a p-value of -0.96 and $p=0.01$.

The occurrence of phlebotominae sand flies reaffirms the tendency to a greater presence of vector-borne zoonotic diseases in neighborhoods with more negative sustainability indicators. A 22% lower annual mean (13 percentage points) was observed in the household infestation index in Lagoa Azul, which has the best NSI of the three neighborhoods studied, while Redinha exhibited the worst sustainability index in the investigation.

Data comparison shows a correlation between the neighborhood sustainability index, which expresses urban, environmental and socioeconomic conditions of the areas according to IDS Brasil 2008, and the occurrence of vectors for dengue fever, AVL and ATL, where neighborhoods with worse indicators show a tendency to exhibit a larger number of insects.

Figure 3 - Tendency of the Household Infestation Index to phlebotominae sand flies in relation to the Neighborhood Sustainability Index (NSI).



CONCLUSIONS

The presence of arbovirus vectors such as *A. aegypti*, *A. albopictus* and *H. leucocelaenus* (Medeiros et al. 2009) and other zoonosis transmitters, such as *L. Longipalpis* (Ximenes et al. 2007) in areas of native vegetation near densely urbanized environments should cause concern, given the high potential risk they pose. Environmental control policies aimed at improving the sustainability parameters of these regions need to be implemented.

Efficient infrastructure services including regular trash collection, basic sanitation and clean drinking water, as well as better socioeconomic indicators such as high per capita income and literacy rates seem to be associated to a decrease in insect vectors in a given region.

The results demonstrate that knowledge of urban and socio-environmental conditions of endemic regions, rather than socioeconomic conditions alone, is an important parameter to consider when seeking to determine causes and formulate or redirect policies aimed at controlling endemic vector-borne diseases.

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