# An Investigation of Hantavirus in Panamá

## Considering the Ecosystem Approach to Health

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McGill University, 2003

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# An Investigation of Hantavirus in Panamá
-Considering the Ecosystem Approach to Health-

## Executive Summary

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Hantavirus was a new emergent infectious disease in the Americas, however only appeared in Panamá in the year 2000, when an outbreak occurred in the Los Santos province. Since the outbreak the Gorgas Institute has initiated a series of multi-disciplinary investigations in the area. Beyond surveys of the human population, blood samples are continually being drawn from both human and rodent populations and ecological analysis of the environment is underway.

The internship project we focused on was an investigation of the prevalence of hantavirus in the context of an ecosystem approach to health. In particular we created and analyzed a rodent trap database of two communities for the Gorgas Institute. This was considered within the context of hantavirus in Panamá, and the traditional medical ideology was contrasted to a new ecosystem approach to health.

In order to create the database we learned how to use EpiInfo6 software and input data from the trap samplings performed in the two communities. After entering all the data, we used the different prompts within the database to create different cross-tables, means and frequencies for the individual variables. These variables were then graphed in order to determine that their distribution was normal. Next, we did several statistical tests comparing mean values across different variables (including the two communities, grid types, and cultivations) and used a non-parametric statistical test to test for significance. We then considered the analysis in the socio-economic and environmental context of these two communities.

Although we found several significant differences between the trap variables –for location, grid type, and cultivation- the small sample size of the database made the findings relatively insignificant. Using our field experience with Gorgas and information that we gathered from local experts, we investigated and evaluated the current state of Hantavirus in Panamá. We then examined the approach of the Gorgas Institute's investigation of hantavirus, and their search for solutions. We found that they had adopted a quasi-ecosystem approach to the outbreak and were looking at solutions for prevention of the syndrome beyond the clinical scope of traditional medicine. However, further efforts would be necessary in order to truly evaluate and understand the multi-dimensional nature not only of hantavirus but of health in general.

An ecosystem approach to health is a recent innovation that is continually growing. This approach has potential to offer the best hopes for long-term solutions to health problems, including emerging diseases like hantavirus.

# Una Investigación de Hantavirus en Panamá
-Reconocimiento del enfoque ecosistema de la salud-

**Resumen Ejecutivo**

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Hantavirus era una nueva enfermedad infecciosa en las Ameritas, pero solamente aparejó en Panamá en el año 2000, cuando hubo una epidemia en la Provincia de los Santos. Después, el Instituto Gorgas (ICGES) inició una serie de investigaciones en diferentes aspectos del área. No solamente están haciendo encuestas en las poblaciones de roedores y humanos, pero también los analizas geográficas.

El proyecto de pasantía fue de investigar la prevalecía de hantavirus con un enfoque ecosistema de salud. Para dar al ICGES, hicimos una base de datos sobre las trampas de roedores en dos comunidades. Estudiábamos el hantavirus en Panamá en general, y la ideología de la medicina tradicional era contraste con el enfoque ecosistemática de la salud.

Para crear la base de datos, aprendimos como utilizar y entrar datos en la programa de EpiInfo6. Utilizábamos el programa para crear mesas y frecuencias de datos. Hicimos gráficas y veamos que los datos no eran en distribución normal. Entonces hicimos pruebas estadísticas para comparar las medias de variables por: las comunidades, las redes y los cultivos. Finalmente discutimos las resultadas en el contexto socio-económico y ambiental de las dos comunidades y la Península Azuero.

Encontrábamos resultadas estadísticas significativo pero el tamaño chico de muestras nos da resultadas relativamente insignificantes. Con nuestra experiencia de campo y información de expertos locales, investigamos y evaluamos estado de hantavirus en Panamá. Después examinábamos el enfoque del ICGES en la investigación y el busco para soluciones. Descubrimos que ICGES esta haciendo investigaciones de muchos diferentes aspectos y que esta mirando la problema del epidémico –y de la salud en general- de más perspectivas que la medicina tradicional.

Una enfoque ecosistema a la salud era una nueva innovación que esta siempre creciendo. Este enfoque tiene mucho potencial para ofrecer las mejores esperanzas por soluciones a largo plazo a los problemas moderno de salud y enfermedad, incluyendo enfermedades emergidas como el hantavirus.

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**Number of Days spent on Project in Panama:**

| | | |
|---|---|---|
| January 9th | City (Meetings) | 4 hours |
| January 16-17 | City (STRI, Meetings) | 12 hours |
| January 23-24th | Field | 16 hours |
| January 30th-31st | City (STRI, Gorgas meetings) | 16 hours |
| February 6-7 | City (work at home) | 16 hours |
| February 12-14 | Field | 16 hours |
| February 20-21 | City (Researching at STRI) | 12 hours |
| February 27-28th | City (Epi info 6 with Maritza) | 16 hours |
| March 10-12 | Field | 2 days |
| March 14-15 | City (Maritza, STRI Research) | 16 hours |
| March 21 | City (Research & presentation) | 8 hours |
| April 3-4 | City (research, Gorgas) | 2 full days |
| April 7-12 | City (Worked on database) | 6 days |
| April 14-15 | City (database, presentation) | 2 days |
| April 16 | Formal Presentation | 1 day |
| April 17-23 | City (worked on internship) | 7 days (and nights!) |

Total number of hours: at least 292 hours each! Or 36.5 days

Total number of days in Panama: approximately 32.5

Total number of days in the Field: 4 days

## INTRODUCTION

During our four month stay in Panamá, we had the opportunity to work with el Instituto Conmemorativo Gorgas de Estudios de la Salud (ICGES) for our McGill Panama Field Study Semester Internship. The Gorgas Institute was founded in 1921 and began functioning in 1928. It was named in honour of Dr. William Crawford Gorgas who proved vital to the eradication of yellow fever and malaria during the construction of the Panamá Canal. In 1990 the institute was reverted to Panamá and has since become an executive unit of the Ministry of Health. With the guidance of director Blas Armién, the Gorgas Institute focuses on the control and prevention of tropical diseases as well as the promotion of education and awareness for general health.

The Gorgas Institute became intimately involved in hantavirus investigation after the outbreak in 2000. Since then it has accumulated several years of samples and pathology of rodents and the human population in the Los Santos Province. For our internship we were asked to produce a database on the effectiveness of rodent traps and to statistically analyze it. The database was based on studies in two communities which will remain anonymous at the request of the Institute.

In addition to studying the database for the Gorgas Institute we investigated the context of hantavirus in Panamá and took an ecosystem approach to the issues of health and emerging diseases such as Hantavirus.

## OVERVIEW OF HANTAVIRUS

Hantavirus pulmonary syndrome (HPS), caused by the Sin Nombre virus, was the first hantavirus to be discovered in the Americas, after several clinical cases of acute respiratory failure were diagnosed in the United States in 1993 (Engelthaler 1999). The five patients affected by this virus died within five days of each other after a brief but fulminant pulmonary illness (Johnson 2001). In just over one month, this virus was isolated as a hantavirus closely related to two Eurasian viruses, Prospect Hill and Puumala, both causing hemorrhagic fever with renal syndrome (HFRS). With the help of modern technology (primarily the polymerase chain reaction, PCR) and diagnostic tools, the discovery of this hantavirus lead to the further and rapid discovery of many more new and candidate hantaviruses in the Americas. Retrospective studies were then done to confirm the occurrence of hantavirus diseases from at least 30 years previously, and it is certain that this virus has been present in deer mouse populations long before humans invaded the Americas (Briggiler, 2001).

In contrast to the HFRS, HPS targets the pulmonary system and causes respiratory failure, pulmonary edema and often cardiac failure with a mortality rate of 40 to 45% (Bayard et al. 2000). Symptoms are often flu-like, with patients suffering from fever, myalgia, headache, cough, and gastro-intestinal symptoms progressing to respiratory failure, pulmonary infiltrates, hypotension and thrombocytopenia (Bayard et al. 2000).

North American HPS is quite different from the Old World hantaviruses that cause HFRS. In contrast to HFRS, HPS occurs primarily in the lungs, and manifests itself in a less conspicuous manner, which makes the disease seem to strike without warning. The nature of HPS that causes cardiac depression also makes patient management an intensive care crisis. In terms of treatment, viral therapy developments are underway, but this treatment is controversial because the crisis often lasts no more than three days (Johnson, 2001) and the illness –causing capillary leakage- stops as quickly as it started.

Hantaviruses are predominantly rodent-based, and are transmitted through inhalation of aerosolized excreta from an infected rodent host. Because of the closely tied evolution of the virus to a particular rodent host, the patterns of hantavirus distribution are often relatedto the geographical ranges of their evolved hosts (Mackow 2001). Current data suggests that both co-speciation of hantavirus with their specific rodent hosts and bio-geographic factors (allopatric migrations, geographic separation, and isolation of rodent host populations) have played important roles in establishment of the current genetic diversity and geographic distribution of hantaviruses (Plyusnin and Morzunov, 2001). Although there are questionable epidemiological observations that suggest human-to-human transmission for some hantaviruses in Argentina, this form of transmission remains unproven for most strains of HPS, and is therefore not a large concern (Wells et al. 1997). There is evidence that rodents in contrast, have the capacity for horizontal transmission of the virus and it is thought that once a rodent reservoir is infected with hantavirus, the animal remains infected for life and suffers little from the virus. Understanding the ecology of hantavirus improves our ability to understand and anticipate virus outbreaks (Wells et al. 1997).

As of 2001, Hantavirus in North America has been occurring mostly west of the Mississippi river, with the ironically named Sin Nombre virus (SNV) being the leading cause of disease. Different strains of hantaviruses now affect almost all parts of the Americas, and are especially concentrated in South America.

## HANTAVIRUS IN PANAMÁ

In January 2000, Panamá became the first Central American country to suffer from an outbreak of Hantavirus, after several deaths and illnesses due to an atypical pneumonia virus occurred in the Los Santos province in the Azuero Peninsulá of Panamá (Bayard et al. 2000). The cause of this mysterious outbreak was investigated by Ministry of Health in conjunction with the ICGES, and the HPS epidemic was diagnosed and later confirmed by the Center for Disease Control (CDC) (Abrego 2000). As the number of cases increased the Minister of Health and President Mireya Moscova called for an official State of Emergency for Public Health. Due to the high risk of increasing spread of disease, the long-planned Carnival celebrations in the region were officially canceled, causing huge economic losses in the region (Camero 2000).

Since the initial outbreak the ICGES, has been successful in isolating the virus strains and their rodent hosts. They also instigated and have been continuing ongoing investigations monitoring and sampling both the human and rodent population in both affected and affected regions in the Azuero Peninsulá. Of primary interest to ICGES is to look at infectious disease trends taking place in order to promote preventative health, well being and education.

Since the beginning of the outbreak in 2000, there have been 38 confirmed cases of hantavirus in the country: classified either as a case of HPS, illness caused by hantavirus or infection by hantavirus. The difference between the three classifications lie in how sick the affected patient becomes: illness, showing clinical signs and symptoms of sickness, or simply showing seropositivity upon blood tests, respectively. The two hanta viruses that have been confirmed in Panamá are the Choclo virus, and the Calabazo virus, each carried by the respective rodent species *Oligoryzomis fulvesens* and *Zygodontomys brevicauda*.

Clinically HPS in Panama has been shown to have three different phases; the febrile phase, cardiopulmonary phase, and the convalescence phase (D.A Enria et al). The febrile phase averages 5 days in length but can last from 1 to 17. Most people suffering from this phase of the virus have symptoms including fever, general discomfort and malaise, myalgia, headache and vomiting and nausea. Less prevalent are symptoms of arthalgia, abdominal pain, pharyngitis, anorexia, diarrhea and lumbar pain. In the cardiopulmonary phase, patients suffer from hypotension, cough, tachycardia, tachepnea, exertional dyspnea, non-productive cough and paleness. This phase can have three categories based on severity, and patients in this phase are usually hospitalized from 17 to 60 days. Following this, the majority of patients had a fast recuperation accompanied by fatigue. To date, there is no specific treatment for this virus. In some countries, anti-viral medications have been used but have not shown favorable results (Ministerio de Salud de Panama, 2001). The Panamanian strains of virus are significant because they more readily cause hantavirus cardiopulmonary syndrome (HCPS) rather than HPS, with a more pronounced cardiac phase of infection. In HCPS death is usually due to cardiac failure and not pulmonary edema as is the case for SNV (Gracia et al. 2001). The recent nature of this disease, both in the Americas and in Panamá in particular means that there are constantly new scientific developments helping to contribute to the knowledge, not only of the etiology of the disease but also of its treatment.

For the Panamanian outbreak of hantavirus in particular, climatic and environmental factors might have contributed to the growth of rodent populations and an increased human exposure to rodents. In the case of Los Santos increased precipitation associated to an El Niño was linked to an increased abundance of primary production and insects. This increased resource base could have caused bottom-up effects in the food chain causing increased number of rodents in the region (Engelthaler 1999). This population growth would have increased rodent-to-rodent interactions and virus transmission. Likewise chances of rodent-to-human interactions would also have increased, spreading the virus and increasingly the likelihood of the outbreak. Surprisingly, little is known to date about the biological characteristics of hantavirus persistence indicating a need for further research (Jonsson et al. 2001).

## METHODOLOGY

The data accumulated from the ICGES' numerous ongoing studies needs to be organized and analyzed into different databases. Of particular importance are the human and rodent surveys as there are several teams working to compile information on these populations, as well as the ecological and socio-economic aspects.

### Human Population Sampling Methodology

The studies on the human population have taken several forms. In addition to interviewing families in high risk areas, many members of communities voluntarily participate in blood tests. For these 'encuestas' a team of approximately 7 people will visit different households and hold interviews with the entire family. An additional census concentrated on the household infrastructure is done by the head of each household. Consent is obtained from each individual family member and both the interviews and the blood tests are voluntary. In any instance where a subject does not want his or her blood taken, the decision is respected by the sampling team.

In the interviews general personal information is gathered, including full name, age, sex, marital status, occupation and Panamanian identification number. Information on past or present illnesses and possible exposure to hantavirus is then solicited. The degree of exposure to rodents and rodent-friendly habitat through different activities is assessed for each individual. For each household the team determines: the physical nature of the infrastructure (what kind of material is used for the floor, walls, roof, etc…), the nature of the surrounding environment (existence of brush, fields, woods or other cultivations) and finally, the number and type of domestic or semi-domestic animals.

The interviews where blood samples are drawn tend to be concentrated around households in close proximity to a Hantavirus-positive person. In these samples each consenting member of the household over two years of age has a blood sample drawn that is later analyzed for seropositivity. The results of these tests are then compiled at the ICGES Institute into a database of the human population. In addition another team delivers the positive or negative results to the different families tested.

We were fortunate enough to be allowed to accompany a team on several interviews in the Tonosí region when blood samples were drawn. These households had been part of a long-running study on the prevalence of Hantavirus in the area. The households in this rural region were often surrounded by cultivation fields and the houses themselves ranged from shacks to more extensive cement-block houses. With the exception of the one man, every member of each family consented to both the blood sample and the survey. There were 9 children between the ages of 3 and 10 who participated. A nurse or doctor drew the blood from the patients while the others interviewed different family members. Samples were stored in a freezer and used needles and medical tools were discarded into a bio-hazardous bin to be disposed of in proper facilities at the laboratories in Panamá City. The families had been forewarned of the impending visit from the Ministry of Health and in general all family members were present. However in one case one of the women had left for the day, and she was subsequently omitted from the study.

Clearly this population sample is not random, as the tests are focused on areas near Hantavirus positive patients, nor are they completely thorough due to their voluntary nature and the fact that people are sometimes not present during the process. Although their non-random nature makes them difficult to statistically analyze, the test has merit as it gives information on the nature of Hantavirus in the region over a time frame of several years.

**Rodent trapping methodology**

In order to gain a better understanding of the nature of the rodent vectors and the prevalence of hantavirus, the ICGES Institute is performing ongoing trapping of rodent populations in various parts of the country. The trapping procedure is largely based on that of the Center for Disease Control’s “Methods for Trapping and Sampling Small Mammals for Virologic Testing” which outlines methodology for trapping biohazardous vectors of disease.

We had the opportunity of joining a ICGES team for several days while they were trapping in the area of Cacao and Aguabuena in mid-February 2003In the evening, traps are laidd in the chosen location and left overnight to be checked the following morning. Traps are set in either a circular or a quadratic grid. The 100 traps in the quadratic grid are arranged in a ten by ten square; with each trap spaced approximately 10 metres from one another; the quadratic grid covers an area approximately 1 hectare in size. In contrast, a circular grid has traps laid out in 12 lines that converge to an epicentre. Each line has 12 traps on it, with a total of 144 traps in the entire grid covering an area of 3.14 hectares. The large size of the grids means that they often overlap several different cultivations or ecological areas. For each sampling site the ecological aspects are recorded, a map is drawn and ecological variables (altitude, temperature, weather, etc…) are measured.

The traps used are Sherman live-capture traps which have trap doors on hinges sprung by motion. The night prior to sampling, a bait of molasses mixed with corn is prepared and approximately a tablespoon is placed in each trap. The following morning each trap is checked for rodents or other animals and those containing rodents are removed and replaced with freshly baited ones. The potentially biohazardous nature of the rodents entails a high degree of safety in the sampling procedure. In theory, the CDC outlines a safety procedure for both the checking of traps and the processing of rodents that would preclude any inhalation of aerosolized rodent excreta. However, the actual sampling by this team was not done accordingly. Traps were checked by opening the door of the cage and nothing was worn to prevent inhalation or physical contact with potential excreta. Although we were advised to hold traps containing rodents downwind this was the only safety requirement in the verification of the traps. Several of the traps at each site were covered in painful fire ants, drawn to the moist bait. The traps containing these and other animals were counted and their location indicated on the ecological map of the trapping site. At each site one member of the team was responsible for noting the location of trapped rodents, traps containing non-rodent animals –be they ants, chickens, etc…-, missing traps, and traps that had been disturbed or were found empty with the door closed. The traps containing rodents were then placed in the back of the pick-up for later processing, and the team would move onto the next sample site.

In our visit a total of five sites were sampled each over the same three day period, the sites included: a pasture, a household, and cultivations of watermelon, corn and tomatoes. After each site had been checked and the rodents collected, the team moved onto the location where the rodents were dissected and processed.

In the actual processing of the rodents, the team practiced more thorough safety procedures, including wearing a vacuum-aerated hood, surgical gown and gloves. The traps were checked and the rodent species identified as Hantavirus vectors were processed first. The rodents from each trap were knocked into a plastic bag and anaesthetic was injected into the bag. Each rodent was then labelled with a numbered tag indicating its sex, the date of trapping, and its species name. A blood sample was taken by cardiac puncture, or preferably through the retro-orbital plexus. After blood samples were taken the physical characteristics were measured, including:

- Species, sex, relative age (juvenile, sub-adult, adult)
- Length of tail, body, ear, paw
- Weight
- Presence and location of scars
- If male: if testicles are visible, if so their length and width
- If female: open or closed vagina, presence of breasts (big or small), if pregnant length and number of foetuses.

The rodents were then dissected and vital organs removed (heart, lungs, kidney, spleen) to be checked for the presence of hantavirus. The samples were stored in a liquid nitrogen tank and the rodent carcass was disposed in a plastic garbage bag. After each rodent had been processed the site was cleaned with alcohol and the non-biohazardous garbage burned.

For the host product, we constructed and examined an EpiInfo6 database on the traps for capturing rodents. The information was obtained from the trapping information sheets. Several variables were measured and comparisons between different variables were analyzed. In the field, the teams noted for each sample site (with variable names in bold):

- Date (**fecha)**
- Location (**localidad**)
- Name of the cultivation (or the overlapping cultivations) **(nombredct)**
- Trap pattern: circular, or quadratic **(redcuad)**
- Number of traps **(ntrampa)**
- Number of rodents captured **(nroedorcap)**
- Quantity of disturbed traps (those traps that had been found with the doors closed but empty, or knocked over) **(ntrampcv)**
- Number of missing traps (removed from grid for whatever reason) **(ntrmapex)**
- Number of traps occupied by other animals (ants, chickens, frogs, etc…) **(ntramcoc)**
- Number of broken traps **(ntrampda)**
- Number of newly captured rodents **(capnuevo)**

- Number of repeat captured rodents
- Number of recaptured rodents

The analysis was done on trap information sheets taken for two communities on the southern tip of the Azuero Peninsula. The samples had been done in November and December of 2002. After entering the data, we examined the different variables and using the database, created different analyses of the database and the variables.

In examining the different variables we noted several things. For the specific trap data that we had been given to analyze there were no repeat captured rodents, nor recaptured rodents. These variables were thus disregarded for the remaining analysis of the database. The number of newly captured rodents was identical across all sample sites to the number of rodents captured. These variables were thus redundant, and we used them interchangeably throughout the analysis.

In order to gain a better understanding of the actual trapping procedure we created two new variables in the database: the number of effective traps, and the overall success rate of trapping for each sample site. Using EpiInfo6's capacity to define and create new variables (using the commands **define** and **let**) we created the variable for number of effective traps by taking the total number of traps and subtracting the number of compromised traps (removed, broken, occupied by non-rodents and disturbed). Therefore:

**Number effective traps = ntrampa – ntrampda –ntramcoc –ntrmapex -ntrampcv**

This new variable was then used to create the success rate. This gave an idea of how successful the effective traps were in actually capturing rodents. It was created by taking the total number of rodents captured and dividing by the number of effective traps.

**Success rate = nroedorcap / number effective traps**

The CDC's manual on the trapping of small mammals suggests that a success rate of 10% or more justifies repeat sampling in the same location.

Having examined the different variables we used EpiInfo6 to output tables, frequencies, and means for each variable. We then examined the possibilities of cross-tables, sum-tables and cross-means for different variables. We decided to examine the difference in variables across locations, cultivations and grid types. We felt that this would give us the best idea of how trapping methods can differ across sample sites, as well as perhaps providing direction towards solutions or adaptations responding to these differences. We graphed the frequencies of different variables and determined from the distribution of variables and the small sample size of the trap data that it was not normally distributed. For our statistical analyses we did not use ANOVA tests, but rather chose the non-parametric Mann-Whitney. This test determines whether two samples of a variable are significantly different. The null hypothesis of no difference between the samples was rejected if the p value was less than 0.05. The comparison of means also allows for comparison of groups with different number of sample sizes.

Using this statistical test we analyzed whether variables had significant differences between the two locations, the different cultivations or the different grid type (circular or quadratic). We then created bar graphs of the different means of the variables across the locations and cultivations.

# RESULTS

## Rodent Trap Database

We found several statistical differences across each of the variables. Between the two locations –Location A and Location B- we found significantly different results in the mean number of rodents captured, the mean number of disturbed, the mean number of missing traps, the mean number of occupied traps, and the mean number of effective traps. There was also significant difference between the cultivations for the mean number of captured rodents, the mean number of disturbed traps, the mean number of occupied traps, the mean number of effective traps, and the success rate. The number of rodents caught and the success rate proved significantly different across the different grid types. For p values larger than 0.05 we did not find significant differences between the groups of variables across location, cultivation or grid type.

In terms of the actual distribution of traps, there were more trap samples done in Location B than in Location A. In Figure 1, one can see the disparity in the distribution of total and effective number of traps between the two

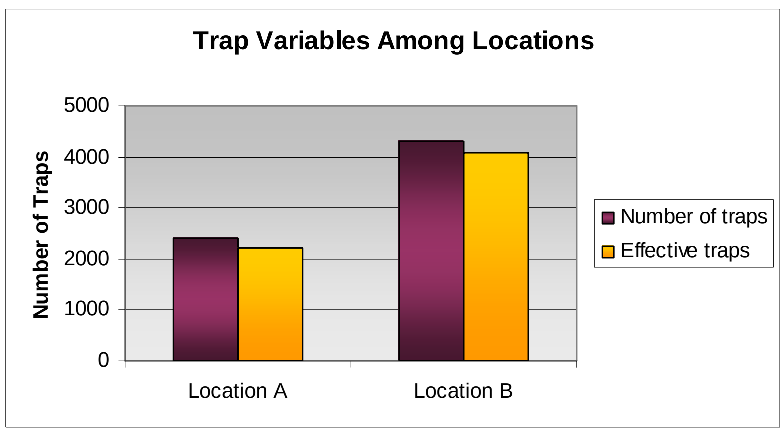



**Figure 1:** Total number and effective number of traps between the communities.

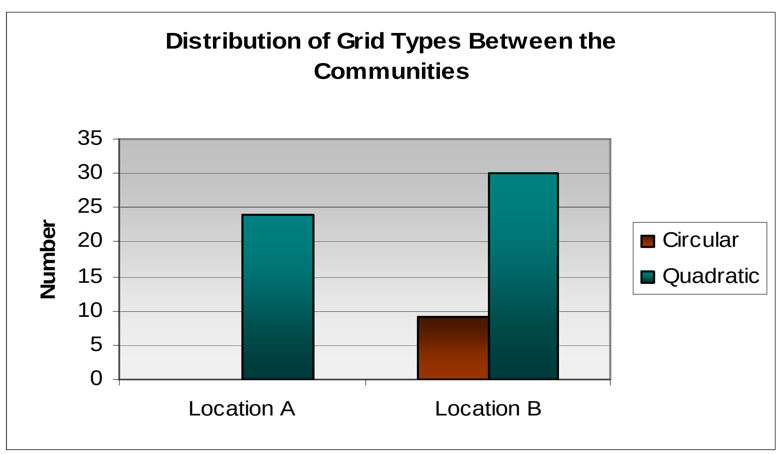
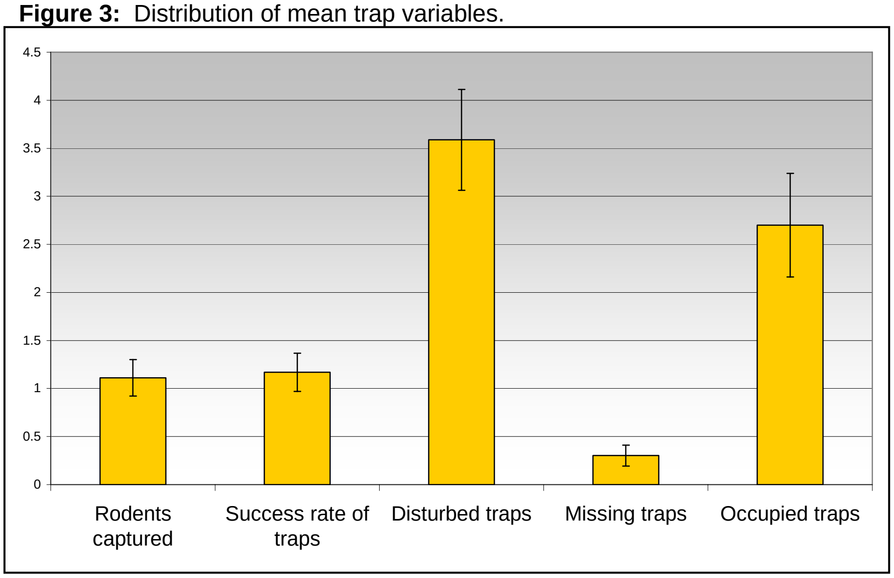



**Figure 2:** Distribution of grid types between the two communities.

communities. Likewise the distribution of quadratic and circular traps was not even between the sites –as seen in Figure 2. The use of variable means for comparison made this disparity inconsequential in the actual analysis of the data.

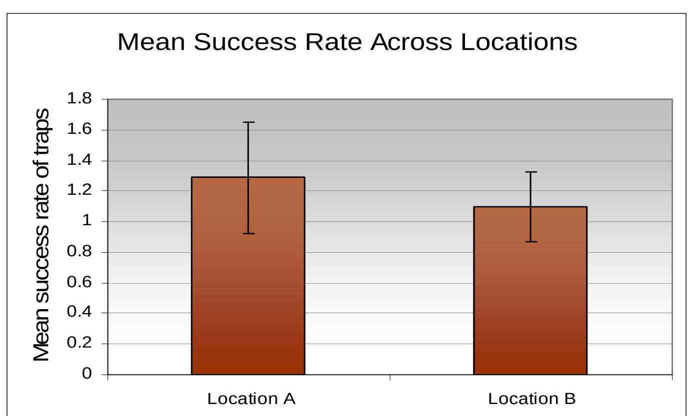
The actual mean values for the different trap variables are shown in Figure 3; these means represent the mean number for each variable per sample site. The mean success rate was equal to 1.168%, which is significantly lower than the value suggested to warrant re-sampling at a specific site (Center for Disease Control 1995). Re-sampling in areas with a low success rate might cause the low number of rodent capture rates, evident in our mean capture rate of 1.111 rodents per sample site. Figure 3 indicates that the largest problem in the trapping of rodents is disturbed traps. These traps are often found with doors closed but nothing inside –perhaps having being triggered by being bumped or knocked during the night. A high number of disturbed traps leads to higher numbers of ineffective traps and might impact the number of rodents caught at a sample site.

**Figure 3:** Distribution of mean trap variables.



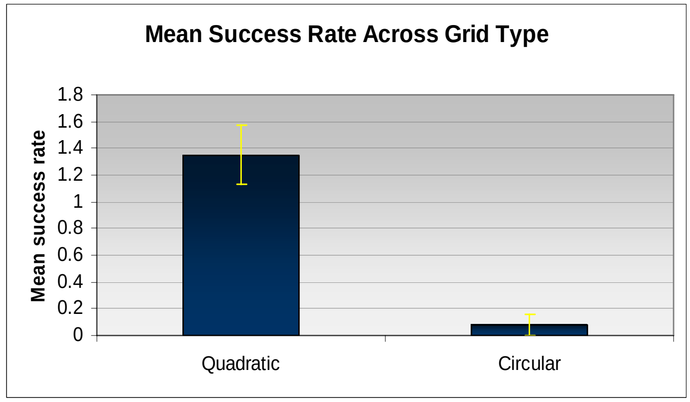

Interestingly we did not find a significant difference in the success rate of traps between Location A and Location B,

**Figure 4:** Success rate of trapping across location.



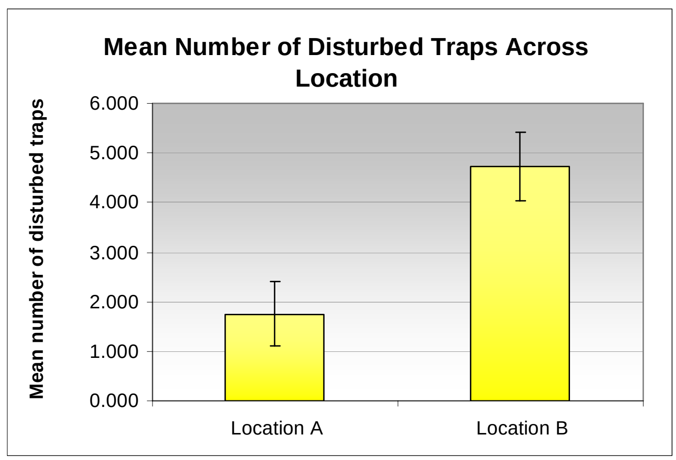
as shown in Figure 4. However the success rate did show significant difference across the different cultivations, as well as across the different grid types (see Figure 5). It is hard to make inferences about the difference in success rate among the cultivations due to problems in the convoluted definition of the cultivation variable. However, the significantly different success rates between the grid types might be due to the fact that the traps in a quadratic grid are more concentrated than in a circular grid. This might cause an increased rate of encounter between the rodents and the traps. Nonetheless even in the quadratic traps, the success rate is significantly lower than the 10% suggested by the CDC to warrant re-trapping in the area.

**Figure 5:** Mean success rate of traps across grid type.




Other variables that showed a significant difference across location included the mean number of disturbed traps, the mean number of occupied traps and the mean number of missing traps. For the disturbed traps, there was a considerably larger problem of traps with doors closed but empty inside in Location B (see Figure 6). Perhaps in this area trapping was done near livestock and the traps might have been triggered from the exterior by physical disturbance.

**Figure 6:** Mean number of disturbed traps between locations.



The mean number of traps removed per sample was larger in Location A than in Location B, as seen in Figure 7. Problems with missing traps often occur when the traps are removed from the grid by people who attempt to use them to trap food.

There is also a statistically higher number of occupied traps in Location A than in Location B. This variable might be more affected by the differences in ecology rather than socio-economic ones between the two regions. Perhaps Location A has a larger number of small animals that might become trapped within the traps.

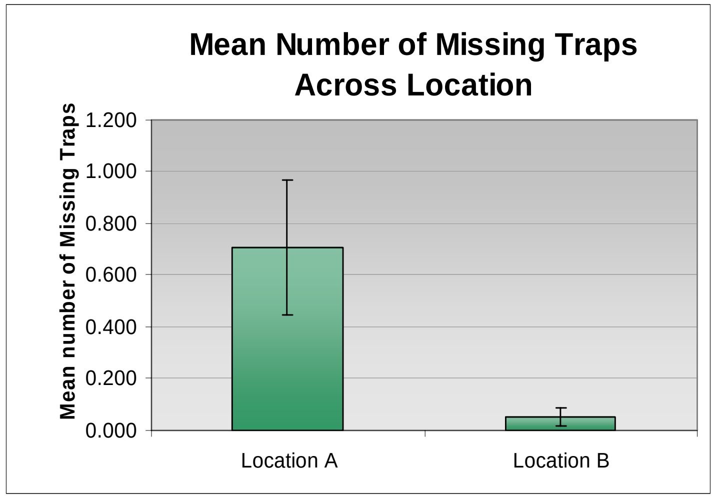



**Figure 7:** Mean number of missing traps across location.

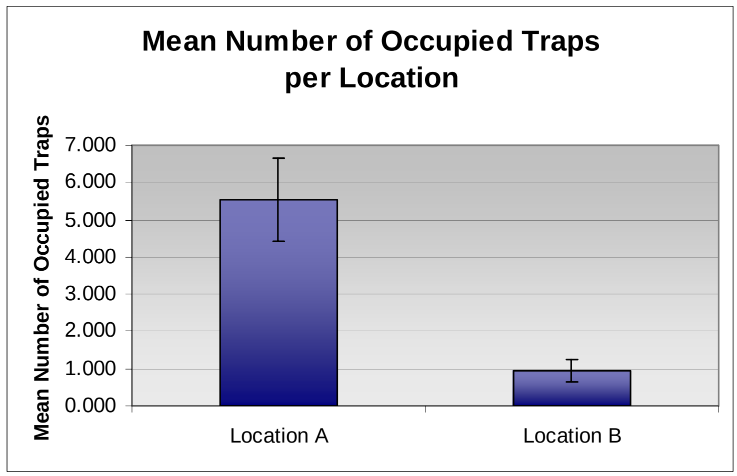



**Figure 8:** Mean number of occupied traps across location.

# DISCUSSION

## Rodent Trap Database Analysis

The actual statistical significance of this trap analysis is low, largely because of the small scale of the study and also because of problematic variables. The study would have to encompass a larger time frame (that spanned both the wet and the dry seasons of Panamá), a larger number of samples, and a larger area in order to be more significant. Likewise there would need to be a redefinition of several of the variables in order to obtain more relevant information from the analysis. This is especially true in the definition of the cultivations sampled. The grids –be they circular or quadratic- often span several different cultivations or ecological regions. They are then defined as the sum of the cultivations, for example: rice-pasto-vivienda. Ideally, grids would only be set in one type of cultivation, however if they absolutely must overlap then they should be identified by the most prevalent cultivation. In this way it would be possible to truly examine the individual effect of the cultivations on each trap variable. In the present situation one cannot separate out the different cultivations from the conglomerated value of rice-pasto-vivienda and thus there is less value in comparing variables across cultivations.

Despite the comparative irrelevance of the cultivation variable, it is interesting to see that there were statistical differences between the two regions for several of the variables examined. These variables might be better understood if the regions themselves are looked at more closely. The two locations, both situated in the Azuero Peninsulá and only separated by approximately 50 km, are quite dissimilar in terms of ecological and socio-economic settings, which might explain some of the statistical results of the trap analysis.

## Descriptions of each location and demography

*Comparison of the Province of Los Santos to the Statistics for the Republic of Panama:*

In order to obtain an idea of the areas studied, it is important to look at characteristics of the province of Los Santos in comparison to the rest of Panama. To do so, we collected the most recent census data and combined this with our general observations from our visit to the affected and sampled areas.

For the statistics on number of occupied houses, there are on average 4.1 people who live per dwelling in the country of Panama, and only 3.3 per dwelling in the Province of Los Santos. For both territories, there are more people who live in individual permanent dwellings than in apartments, or rented rooms in houses. This is significant because many development reports show an inverse relationship between family income and number of children per family or size of family. If the number of people living per dwelling is smaller than average, or the family size is small, we can vaguely assume that the people from the area are not suffering financially, despite there being many more factors involved in these situations.

For both the Republic of Panama and Los Santos Province, there are three categories that employ the highest percentage of people. Limited census data does not allow us to extrapolate what specific occupations the populations of the two Locations have, however, we can attempt to draw conclusions to their practices from the provincial averages. The top three types of employment are: (1) agriculture, livestock, hunting and silviculture, (2) Gross and small-scale commerce, vehicle repairs, motorcycles, personal effects and domestic goods and (3) working in manufacturing industries. The national and provincial percentages for these practices are respectively as follows: 18.2% and 31.6%, 18% and 13.7%, and 9.3% and 8.4%. This shows that on average a much higher percentage of the population works in and relies on agriculture; an important fact relating to hantavirus exposure that will later be discussed.

In terms of employment, 50.6% of the population of Los Santos Province is eligible to work, with 92% of those actually employed. Although fewer people are eligible to work in the Province of Los Santos in comparison to the National percentage, which stands at 52.6%, a greater proportion of the Los Santos population actually does work, with the national rate at 87% (2000 Census, Republic of Panama). However, when one compares the average income per job between the Los Santos Province and the Republic of Panama, the Los Santos Province monthly income is less than the Panamanian average for all occupations.

Although these numbers mean very little statistically, they do offer us a glimpse of life in the Province of Los Santos in comparison to the rest of the country. What is more helpful, is to look directly at the census data of the two communities that we focused on for the trap samplings.

*Comparison of the Locations A and B:*

Although we did not personally visit these communities, investigations and discussions with people familiar with the area as well as our visits to other communities in the Los Santos Province have allowed us to understand more about these two areas studied – not only in terms of geography, but in terms of the actual human population and their living conditions.

Both Location A and Location B are found in the Los Santos Province in the Azuero Peninsula on the Pacific Coast of Panama. Although these two locations are not very far from each other, they differ in many respects.

Location A is in a protected National Park on the southern coast of the Peninsula. It is a stretch of land separated from the mainland by a river and is inhabited by 225 people in 72 different houses. In terms of living condition, the main type of house found in this area is visibly below the Panamanian standard (See Photo 1). 61% of these houses have earth floors, and 13.8% of the houses do not have proper toilets, which is a high percentage in comparison with the national average of only 12.7% and 6.8% of the houses having earth floors and toilets, respectively (2000 Census, Republic of Panama). Although 95% of the houses in this area have access to potable water (in comparison to 90.8% of the houses in the Republic of Panama), 45.8% of these houses do not have electricity, which is much higher than the national percentage at 18.6%. 26.3% of the population at Location A still uses firewood as their source for cooking, while only 17.4% of the National population still cooks with firewood. Again they differ drastically from the national average in that 55.5% and 38.8% of the houses do not have televisions or radios, respectively. No house in this community has a telephone.

**Photo 1:** Typical houses in Location A. Courtesy of Dr. Blas Armién.

In terms of the population itself, 56% of the population is male, which is higher than the national percentage of 50.4%. There are, on average 3.1 people who live in each house, lower than the national average at 4.1 inhabitants per lodging. As seen in Table 1, the age distribution of the population in Location A is similar to that of the national average, with the average age on the island identical to the national average of 25 years of age.

**Table 1**: Housing Characteristics based on Percentage and Location (2000 Census, Republic of Panama)

| Location | Total Number of Homes | With earth floors | Without Potable Water | Without Functioning Toilet | Without Electric Light | Kitchen with Firewood | Without Television | Without Radio | Without Residential Phone line |
|---|---|---|---|---|---|---|---|---|---|
| Rep. of Panama | 681,799 | 12.7% | 9.2% | 6.9% | 18.6% | 17.5% | 22.9% | 16.6% | 59.6% |
| Location A | 72 | 61.1% | 4.2% | 13.9% | 45.8% | 26.4% | 55.6% | 38.9% | 100.0% |
| Location B | 184 | 5.4% | 1.1% | 1.1% | 3.3% | 7.6% | 11.4% | 12.5% | 72.3% |

**Table 2:** Population Characteristics based on Percentage and Location (2000 Census, Republic of Panama)

| Location | Total Population | Men | Ages 18 years and over | With Less than three years of schooling | Involved in Agricultural activities | Unemployed | Not Economically Active | Illiterate | With Disabilities |
|---|---|---|---|---|---|---|---|---|---|
| Rep. of Panama | 2 839177 | 50.5 % | 62.2% | 8.1% | 6.7% | 5.3% | 36.8% | 5.9% | 1.8% |
| Location A | 225 | 56.0 % | 59.1% | 14.7% | 18.7% | 4.0% | 32.4% | 10.7% | 1.8% |
| Location B | 594 | 51.5 % | 77.6% | 5.9% | 13.6% | 2.7% | 35.4% | 4.2% | 1.9% |

**Table 3:** Population Characteristics based on Location (2000 Census, Republic of Panama)

| | Average # of people per house | %age of population under 15 yoa | %age of population between 15-64 yoa | %age of population ages 65+ | Average age of population | Average # years spent in school | Average monthly income of population 10 yoa+ | Average monthly income per hosuehold | Average number of children per woman |
|---|---|---|---|---|---|---|---|---|---|
| **Rep. Of Panama** | 4.1 | 32.02 | 61.95 | 6.03 | 25 | 7.5 | 270.9 | 380.3 | 2.4 |
| Location A | 3.1 | 35.56 | 56 | 8.44 | 25 | 4.7 | 82.5 | 94.8 | 2.8 |
| Location B | 3.2 | 17 | 69.36 | 13.64 | 37 | 7.2 | 168.8 | 325 | 2.2 |

*** yoa = Years of Age**

The population of the island ranks less than the national average for number of years spent in school per person (4.7 in comparison to 7.5), and 13.41% of the population is illiterate on the island, in comparison to 7.62% of the national population. However, only 8.49% of the population is unemployed, almost 4.5% less than the national percentage, which stands at 12.98%. Only 32.4% of the population are not economically active in Location A, while the national population stands at 36.8%. The inhabitants of Location A have, on average, a much lower monthly income with respect to the rest of the country, at $82.50 and $270.9, respectively. The average household income is also significantly less than the national average, at $94.8 in comparison to $380.3. The fertility rate of Location A is higher than the national average, at 2.8 in comparison to 2.4 children per woman. A much larger percentage of the population of this community partakes in agricultural activities, at 18.6% in comparison to the national percentage, which is 6.7% (Census 2000).

Location B is located inland near the East Coast of the peninsula. The town structure is much more typical than Location A, with houses surrounding a central point in town. The houses here, as seen in Photo 2, are much more characteristic of standard Panamanian houses. This town has 594 inhabitants in 184 houses. Only 14.6% of the houses in Location B have earth covered floors, a percentage much closer to the national average of 12.7%. In Location B, only 1.1% of the houses do not have access to potable water, with 1.1% lacking functional sanitary toilets. 3.2% of the population does not have electricity, and only 7.6% cook with firewood. Again, both of these rates fall far lower than the national average, which stand at 18.6% and 17.5% respectively. More homes in Location B have televisions (88.6%) and radios (87.5%), again at higher percentages than the Republic of Panama, which stand at 77.1% and 83.4% respectively. In Location B, there is a higher percentage ( 72.2%) of people who lack telephone lines than the rest of the country, where only 59.6% of houses lack telephone lines.

**Photo 2:** Typical houses in Location B. Courtesy of Dr. Blas Armién.

In terms of the population of Location B, 51.5% of its population is male, only marginally higher than the male percentage of the population of the country, which falls at 50.4%. There are 3.2 people in each house in Location B, again lower than the national average of 4.1 people per house. The population of Location B seems to be older than that of Location A and the rest of the country, as there is a greater proportion of people between the ages of 15-65 and over 65. 17% of the population is under 15, 69.36% are between the ages of 15 and 65, while 13.64% of the population is over the age of 65. The three sets of respective numbers for the rest of the country are as follows: 32.03%, 61.95% and 6.03%. This difference could be due to a number of reasons; one of which might be the migration of young people to the city centers in order to benefit from the perceived better job opportunities (Census 2000).

The average number of years spent in school is higher in Location B than in Location A, averaging 7.2 years, which is slightly under the national rate of 7.5 years. The population of Location B has a greater literate population than both Location A and the national average, with only 4.79% being illiterate (and 13.41% illiterate in Location A and 7.62% in the national average). Again, Location B has a lower rate of unemployed people in comparison to the rest of the country, with it standing at 5.13%, which is much lower than Panama's 12.98%. The percentage of the population who are not economically active (35.4%) lie just below Panama's National average (36.8%). The average monthly income per person and per household (at $168.8 and $325, respectively) are closer to the national average (of $270.9 and $380.3 respectively) than Location A. The fertility rates of women in Location B (2.2 children per woman) are lower than the national average (2.4 children per woman). The percentage of population of Location B (13.6%) partake in agricultural activities less than those of Location A (18.7%), but more than the National Average (6.7%).

**Discussion of socio-economic situation**

After reviewing the statistics of the two locations, it is clear that they differ in many ways. It is important to analyze these differences in order to take into consideration the complex interaction between both the geographical and the social situations in the context of hantavirus. In such a way we might gain better insight and understanding into both communities and how they might be affected by a hantavirus outbreak.

One might first look at the statistically significant difference in the mean number of missing traps between Location A and Location B (Figure 7). This great difference probably has little to do with the physical environment, or the nature of the disease, but more to do with the economic state of the area being sampled. The people in Location A on average have less economic means than those in Location B, and the traps represent a means to catch food. Otherwise, mere curiosity rather than need drives them to remove them from the sampling site. These types of problems must be taken into consideration when considering the number of effective traps used in a location. Not only does this type of analysis and observation aid in deciphering the discrepancies between results, but it also helps us to understand the state of the affected community so proper action can be taken in order to protect the community against further infection.

It is evident by looking at the Census data that those who live in Location A have a lower standard of living than those in Location B. Although those in Location A have access to potable water (a basic amenity) and houses and almost half do not have electricity and none own a telephone. These statistics give us a general idea of the living standards of those inhabiting a region. What is important to us in the context of this study, is how many people have earth-covered floors because these houses prove problematic to rodent proofing –a concept that will later be discussed. It is also of concern how many households still cook with firewood, which might mean that increased deforestation is taking place around the community. If this is the case, then there are potentially more heavily ecologically-altered areas for rodents to invade and inhabit, thus increasing the risk of hantavirus exposure.

The 2000 Census data indicates that Location B is inhabited by a larger proportion of older people than Location A. This could be because more of the younger people migrate to the city, driven by the chance to earn more income. A more elderly population would probably work less in the fields doing agricultural work, and would therefore have less exposure to rodent-vectors through this means.

The census data also shows that there are fewer people in Location A that are educated and literate than in Location B. Although this says nothing of the aptitude of the population, it might mean that educational groups working to increase awareness of health, disease and hantavirus might have to implement their programs differently to adequately reach the population. Community participation must aim to include all members, and strategies incorporating signs and pamphlets might be less useful in these communities.

It is also noteworthy that more people are employed through agriculture in Location A than in Location B. As hantavirus is a virus that primarily affects those working closely in the fields with cultivation, it means that there is a greater chance that those working in Location A will be exposed to the virus. Agricultural cultivations are prime habitat for rodents and therefore vectors of hantavirus; it is for this reason that agriculture is highly correlated to hantavirus exposure. This leads us into what happens when an area is affected by hantavirus; different steps can be taken for prevention on both a local and global level.

## Future Steps in Controlling, Preventing and Treating Hantavirus

### *Prevention on a Community-wide Level*

After the outbreak of HPS in Panama, the ICGES and the Ministry of Health followed a specific guideline created by the Center for Disease Control in order to increase awareness about the problem in both affected areas and the rest of the country.

Now, when the outbreak seems like distant history to many people, one of the main questions is how to prevent this type of outbreak from happening again.

There are many different methods of preventing another outbreak from occurring, and these methods are being explored and developed in Panama as more becomes known about the virus. Until more clear solutions have been reached, general precautions have been made available to the public so that they can protect themselves as best they can from any infected rodents and their excreta. Because these rodents play an extremely important role in their ecosystem, and due to their great population and wide distribution their complete eradication would be illogical and difficult. Instead, the population must take every measure to protect themselves from these rodents. The most realistic form of protection would be to make houses less attractive to rodents as dwellings and breeding grounds.

Multidisciplinary teams in the southwestern United States have introduced effective rodent proofing of homes as prevention against contact with hantavirus. Mechanical rodent proofing involves the use of inexpensive materials to seal dwellings against the entry of rodents (Hopkins et al. 2001). Although this technique has been shown to be effective over winter in seasonally-used cabins, its application to continuously inhabited structures is a more challenging problem that has never been evaluated. They found that inexpensive rodent proofing of occupied rural homes will decrease the frequency and intensity of rodent intrusion, thereby reducing the risk of HPS among rural residents. However, there is no guarantee that such results would occur in the context of Panama. Despite this, some information discussed in this project may still prove valuable in this context.

The technique discussed involves sealing openings around foundations, doors, roofs and pipes, and repairing screens and windows. Because of the typical structure of many houses in Panama, this type of prevention would not be applicable. The rodent proofing of a home in the United States that has a foundation, doors and ventilation systems would be highly different from a home in the Azuero Peninsula in Panama. Many of the homes in Panama (such as those in Location B) are made of cement, do not have screens on their windows, and may have spaces between doors and the ground. Other households, such as those in Location A, may be made of wood with earth floors and have roofs made of palm leaves. These houses would be extremely hard to rodent-proof. Despite the usefulness of the rodent proofing methods in the southwestern United States, this type of prevention is not so applicable to Panamá. Likewise, the realities of the virus in the two communities being studied differ considerably, and different protocols are necessary.

In weighing the costs of prevention it is interesting to look beyond the health consequences to the economic costs of hantavirus. Prevention of this disease is not only important for the well-being of the people, but like other tropical diseases, HPS may have long term sequelae that could further affect the lives of patients (Goade et al. 2001). Following this disease, both somatic and physical complaints are common. Patients may show signs of fatigue, decreased pulmonary function and airway flow, motor weakness in muscle groups, myalgias, arthralgias and poor short-term memory (Goade et al. 2001, Gracia et al. 2001). If a patient exhibits any of these problems post-infection, there is the possibility that it could lead to a decrease the amount of work the patient can do. If the patient can not exert himself as he once did, his decrease in output at work could subsequently result in a decrease in wages. This is where prevention could have economic benefits. It would be interesting to compare the cost of rodent proofing a house in Location A or B, the potential wages lost if infection were to take place. Potential interventions should be explored to prevent the debilitating consequence of HCPS in Panama, taking into account both patients health and the economic benefits of prevention.

*Prevention on a Global level*

On a more global scale of prevention, research is still underway to find different human vaccines against hantavirus (St. Jeor et al. 2001, Ulrich R et al. 2001). Although there are some promising developments, it is a long and strenuous road to successful drug development. Only a small percentage of discovered drugs actually make it to the market, and until then other forms of prevention –such as rodent proofing houses- must be considered. Nonetheless a vaccine would certainly be a desirable method of prevention against hantavirus. In the actual treatment of the disease, several antiviral drugs have been tried on hospitalized patients, however none have shown particular promise.

**Ecological Aspect to Hantavirus**

The strong co-evolution existing between the hantaviruses and their respective rodent hosts has contributed to the closely tied distribution patterns between the two and the wide genetic diversity of different hantaviruses (Mackow 2001). The ecological rodent distribution patterns can be closely mapped to the distribution of different hantaviruses. This is important in Panamá because of its nature as an isthmus and land bridge between the two Americas. Any migration of rodent vectors between the two Americas will be focused through Panamá, and thus so too will the migration of any hantavirus. The occurrence of hantavirus therefore appears to be limited to the geographic ranges of distribution of rodent vectors.

However, the actual links between rodent populations and hantavirus outbreaks are more complex than parallel distribution patterns. Hantavirus had existed in rodent populations in the Americas and Panamá long before an outbreak of the syndrome ever occurred. The ecological dynamics that create the conditions for an outbreak of the syndrome are fairly complex and unpredictable. In essence environmental conditions favourable to high population densities of the rodent vector create the circumstances necessary for an outbreak.

Outbreaks tend to correlate with climatic conditions, for example El Niño, that create ideal circumstances for population increase. Increased precipitation from altered climatic patterns cause increased primary production, and through bottom-up effects, can lead to increased population growth of the rodent-vectors (Engelthaler 1999). The increased populations of rodents leads to increased rate of rodent-to-rodent transmission of the virus. Rodent-to-rodent horizontal transmission is thought to be by physical contact through biting for example, and is the virus main means of transmission. This limits the virus' ability to transmit over large geographic ranges and tends to focus it in local populations of a host. Recent studies in cyclic voles however, have shown that the virus has the propensity to infect local environments which allows it to persist during population crashes either due to cyclic demographics or stochastic events (Pontier et al. 2001). In either case the rodent population increases and an outbreak occurs when a threshold is passed where there exists high human contact with the rodent vectors.

The Azuero Peninsulá is an environment hugely altered by human activity. Most of the region is heavily deforested and used for agriculture; in the rural regions many of the cultivations extend up to the houses edges. This environment facilitates human-rodent interaction, especially considering the majority of the populations' main occupation is agriculture. In the context of the rapid deforestation of the Panamanian forests, this might lead to larger ecosystems for the rodent-vectors of hantavirus. This is important to consider in the context of hantavirus in the future and how human modification of the environment might impact the distribution and prevalence of the virus.

**Ecosystem Approach to Health**

The increasing capacity of humans to change the natural environments they inhabit presents interesting complications in the fight against disease. We must be cautious in our entanglement in these ecosystems and life cycles that have evolved and coevolved over long periods of time; it is under these tampering circumstances that many emerging and re-emerging diseases have developed (Waltner-Toews 2001). To effectively respond and prevent the diseases and epidemics of the present we will need to approach and regard health in a completely new manner from our historical ideology. The ICGES has attempted to incorporate a so-called "ecosystem approach" to Panamanian hantavirus, in its widespread studies on issues beyond the simple pathology and clinical aspects of the virus.

This new approach to health is slowly taking shape and is an ever-changing and learning field. Essentially it mandates adopting a broad spectrum of understanding and investigation in order to find new flexible and adaptable visions and goals for health, within a complex and uncertain world.

In order to truly begin to respond to the problems of health, we need to look beyond our linear and gradual ideology of the world. Clearly our modern conception and focus of health is not working: disease prevention and eradication have proven ineffective. One can easily look to the re-emergence of once ‘eradicated’ diseases or the growing resistance of vectors and bacteria to controlling agents. Topics studied do not occur in a vacuum and the traditional outlook on health –with its primary focus on the individual and the unattainable goal of immortality- does not take into account the holarchic-state of the world, with its complex, ever-changing feedback loops. Our inability to discard the linear mentality when conceiving not only of health systems but of living systems in general leaves us relatively unable to grasp or even begin to understand the interactions around us. These systems are inherently complicated, rent with feedback loops and a propensity for sudden change when thresholds are crossed. To have effective change we must work and negotiate within this system and its reality, looking for a wide spectrum of solutions and acknowledging the need for adaptability and reflection on the multiple outcomes of the different options. Problems need to be approached from many perspectives, for example vaccinations cannot be incorporated without education.

Most importantly, modern medicine fails to accept the necessity of death. The concept of health must incorporate the reality of death. A system inevitably lives and dies, and to prevent this on the long term is neither healthy nor realistic. If we truly wish to reach a state of health that goes beyond the “mere eradication of disease” (World Health Organization, in Waltner-Toews 2001) then we need to understand the context of physical and mental illness in an ever-globalizing world of growing inequality in economic wealth and the emergence of increasing infectious diseases and environmental problems.

Medicine in this new context must go beyond simply looking for band-aid solutions or preventions to disease. It must look for solutions and consequences of actions beyond the immediate impact, to the multiple effects at all levels of organizational structure. In doing so it is important to mobilize the public and seek multi-disciplinary public participation in the search for goals towards a healthy and happy society.

This higher degree of community involvement, not only in the investigation of disease (through participation in the studies that ICGES is undergoing), but in the search for plausible solutions is of absolute necessary to effect real change. Prevention methods will be more effective with direct community involvement, including public discourse and awareness programs so that knowledge is equally disseminated to those who need it most.

In acknowledging and investigating the complex nature of hantavirus –within not only a clinical-pathological system but in the social, economic and environmental realities of Panamá- the ICGES has begun to incorporate an ecosystem approach to the resolution of these epidemics. The consideration of the multi-dimensionality of the problem is imperative if viable and long-lasting solutions are to be achieved. In some cases, the goal of health might be better achieved in learning to live with disease versus eradication. Through programs such as nutrition, increased public health infrastructure, social support networks and economic equity might enable the impacts of disease to be mitigated without necessitating an eradication that might be costly and short-lived (Waltner-Toews, 2001).

If the health is a state of balance and harmony within oneself and the greater environment, coupled with reserves and the capacity to respond and adapt to a changing environment (Waltner-Toews 2001) then perhaps the ICGES is on the right track. However, more strides are necessary towards this concept of health that reaches beyond the mere treatment and prevention of diseases.

The outbreak of Hantavirus in Panamá was the result of a combination of various systems interacting. Disease organisms can increase over time undetected until they reach a climax level where there is adequate contact for an epidemic to explode (Waltner-Toews, 2001). The ICGES has been mapping the interaction of the rodent-vector populations, the human socio-economic reality and climatic and environmental parameters whose interrelations in 2000 directly or indirectly created outbreak conditions. In the acknowledgement of the complexity and multi-dimensionality of disease and public health the ICGES has gone a long way towards incorporating an ecosystem approach to health. Certainly further changes facilitating this process are desirable, including new policies facilitating the integration of information and consequences of actions throughout the social, economic, political, and ecological realms. Collaborative processes must be encouraged between these different faculties and ongoing adaptive management programs in governance, management and monitoring must be created. Although the outbreak of Hantavirus in Panamá had many negative consequences including the loss of lives and economic hardship in the Azuero Peninsulá, one positive outcome might be that the ICGES will become a reference center for the disease in

Central America (Abrego, Mayo 27 2000). Already the institute is involved in a large number of collaborative international studies on the disease, and receives international funding for several of its studies. With the new laboratories being constructed and newly-renovated facilities the ICGES will be able to respond to new outbreaks more quickly and hopefully to create prevention strategies that reach beyond the traditional boundaries of health to a larger ecosystem approach to the promotion of health.

The ecosystem approach to health offers an entire new perspective with an encouraging outlook into the future goal of a healthy and prosperous community and society –not only of Panamá but of the world. With considerable investigation and this innovative approach to solutions the hantavirus outbreak might be avoided in the future and health in general promoted and accessible to not only the human but the natural world.

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