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Science

A History of Guahan's Flora

By Robert Bevacqua, PhD
Science Teacher
Guam High School
robert.bevacqua@pac.dodea.edu

Abstract: *Guahan's history can be traced through its tropical vegetation. The first plants (endemic) developed in isolation on the uninhabited island. Then there were successive waves of plants arriving by natural means (indigenous), on board Chamorro voyaging canoes, Spanish sailing ships, American war vessels, and, most recently, airplanes. Some of the recent introductions have become invasive plant species that have the potential of dramatically changing the island landscape. This presentation will form the basis of a professional development opportunity for school teachers interested in expanding their lesson plans to include island flora and fauna in a historical perspective.*

The most distinguishing environmental feature of Guahan, formerly Guam, is its greenery[1]. The first impression of visitors is of the many vibrant shades of green. The lush island vegetation can be a tangle of trees, shrubs, and vines, but by looking closely at the individual plants that make up the tropical jungle, it is possible to trace the island's history through the verdant flora. The first plants developed in isolation on the uninhabited island. Then there were successive waves of plants arriving by natural means, on board voyaging canoes, Spanish sailing ships, American war vessels, and, most recently, airplanes.

Vocabulary
There are terms that need to be defined before we can trace the island's history through its plants:

> Endemic plants are those that developed in the Mariana Islands and are found nowhere else in the world (Table 1). Some of the wild orchids and the seeded breadfruit or *dokdok* are examples of endemic plants ones are that unique to the Mariana Islands.

[1] Mick Subbert of Guam High School, a biology teacher with 25 years of experience in teaching about Guahan's flora and fauna, provided much of the reference materials used in this article.

Indigenous plants are those that are naturally distributed in the region (Table 2). Their seeds were transported by birds or floated on the sea to the island. They became established before the arrival of humans. Beach mahogany or *da'ok* and iron wood or *gagu* are examples of indigenous trees that were naturally distributed among the islands of the Western Pacific before the arrival of humans.

Introduced plants are those that were transported to the island by humans. These introductions can be classified into three historical eras: Chamorro (Table 3), Spanish (Table 4), and American (Table 5). Coconut palm or *niyok*, for example, was introduced by the ancient Chamorros, pineapple or *pina* by the Spanish, and *tangantangan* by the Americans.

A special classification of introduced plants is the invasive species (Table 6). These are fast spreading weeds, recently introduced, that can threaten forests and farms. Chain of love or *kadena de amor* is an invasive vine that can smother entire trees.

Endemic Plants

Wild orchids, especially the endemic ones, are quick to capture the public's interest. Thirty orchid species have been identified on Guahan and the neighboring Mariana Islands (Raulerson and Rinehart, 1992). Of these, half are found growing on the ground and half are found in trees. Four are considered endemic, seven are indigenous, and the remainder are introductions (Raulerson and Rinehart, 1992). Hikers entering the jungle are often keen to observe endemic orchids flowering in their natural habitat. They are sure to be disappointed. The native orchid plants are rare and difficult to find. But most disappointing are the orchid flowers. The blossoms are tiny in size, a bland white or yellow in color, bloom only seasonally and the flowers may stay open for less than a day. Thus the endemic orchids are a far cry from the showier, purple flowers introduced from Thailand and Hawaii.

The seeded breadfruit or *dokdok* is endemic to the Mariana Islands and is generally found in limestone forests. The starchy fruit was a staple food for the old Chamorros and the wood was valued in boat building and house construction. The feature that distinguishes *dokdok* from *lemmai*, the breadfruit introduced by the Chamorros (Table 3) is the seeds or nuts found inside the large fruit. They can be roasted like chestnuts and eaten as a healthful, after-dinner snack. *Dokdok* is a fast growing tree that can be found in the wild and in home gardens.

Indigenous Plants

The large, sturdy trees with dark green foliage that line the sides of Marine Corps Drive in Old Hagåtña and Anigua are popularly known by their Chamorro name, *da'ok*. These indigenous trees (Table 3) are also know by their various English names, beach mahogany, mast wood, Alexandrian laurel; and their Hawaiian name, *kamani* (Elevitch, 2006). Like the water buffalo or *carabao*, the *da'ok* is a symbol of strength and perseverance. It is among the biggest trees on Guahan and is noted for its ability to withstand typhoons. It has been an important source of wood for handles, carving, construction, and boat building. Palauans, most notably, continue to use *da'ok* in carving story boards.

Chamorro Introductions

The ancient Chamorros have long been recognized as voyagers and settlers of the Mariana Islands, but they also deserve recognition as horticulturists or agriculturists who introduced an important collection of plants to Guahan (Table 3). On board their sailing canoes they transported mostly plants with edible roots or tubers and trees that yielded fruit or nuts (Table 3). The collection contained five important staples of the Pacific Islands: taro or *suni*, yam or *dagu*, breadfruit or *lemmai*, banana or *chotda*, and coconut or *niyok*. The last is regarded as the 'staff of life' by islanders.

Rice or *fa'i* has a unique position among the plants (Table 3) introduced by these prehistoric navigators (Cunningham, 1992). It is a grain crop and is very unlike the other tree and root crops brought by the Chamorro colonists. This has sparked a scientific debate as it was previously assumed rice was introduced by Europeans to the Mariana Islands. Three forms of evidence, historical, linguistic, and archaeological, support the position that the ancient Chamorros produced rice on Guahan. Early European explorers were the first to report rice being grown on Guahan. Modern linguists contributed additional support when they found *fa'i* , the Chamorro work for rice in the field is very similar to the Indonesian word for field rice. In 1971, a Japanese archaeologist studying the ancient Chamorro on nearby Rota discovered the impression of a grain of rice in a piece of pottery. The archaeologist was able to date pottery as a type made long before Europeans came to the Marianas. Despite this evidence, the presence of rice on Guahan continues to be a controversial topic among scientists (Cunningham, 1992), because it would mean the ancient Chamorros were the only Pacific Islanders to cultivate rice in prehistoric times.

Spanish Introductions

The Spanish introduced many fruit and vegetable crops (Table 4) to Guahan. Of these, chile pepper or *donne'* enjoys a special place in island culture, because it gives local cooking its distinctive flavor and heat. Columbus discovered this spice plant in the New World and carried the seed back to Europe. He confused it with black pepper, which explains why it has been mistakenly called 'pepper' ever since. This new pepper quickly spread to African and Asia, including Guahan, along Spain's extensive trading routes. The shape, size, and color of chile peppers can vary greatly. On Guahan, the preferred chile pepper is *donne' pika*. The fruit of which is small, red, and high in pungency or heat. It is commonly grown as a backyard crop and is the central ingredient in *fina'denne,* a popular condiment sauce made with soy sauce, vinegar, and lemon or lime juice. The role of chile pepper or *donne'* in modern Chamorro life is celebrated each year with a festival in the village of Mangilao.

American Introductions

Tangantangan is the dominant vegetation on Guahan. It does not have a common English name. It is a small, fast growing tree native to Mexico and Central America. It was probably brought to Guahan early in the American administration, but it did not become widespread until after WW II. The fighting left large areas denuded. In an effort to quickly reforest the island, t*angantangan* seeds were broadcast from airplanes. The effort was successful and dense thickets formed. Unfortunately the effort was too successful, the thickets prevented the return of native plants. Now *tangantangan* is considered a highly invasive plant species on Guam and in many areas of the tropics. *Tangantangan,* on the positive side, is an important source of firewood, animal feed, and poles for constructing farm trellises and temporary structures.

Invasive Species

According to the Global Invasive Species Database at the University of Auckland in New Zealand, Guahan has the dubious distinction of having four of the world's worst invasive plant species: (1) *tangantangan,* (2) chain of love or *kadena de amor*, (3) African tulip tree, which has no Chamorro name, and (4) Siam weed or *masigsig* (Table 6).

Chain of love is a highly invasive species that is now widespread on Guahan. After *tangantangan*, it is the dominant vegetation on the island. Originally from the Philippines, chain of love is also known by its Spanish name *kadena de amor*. It is not known when it arrived on island, but is thought to have spread in the post WW II era. It can be recognized by its small pink flowers that are produced in clusters of dozens

to hundreds. Despite the beauty of the flowers, it is an aggressive vine or creeper that is capable of completely covering trees - smothering and killing large areas of forest. The death of the trees results in less food and habitat for wildlife, such as the island's endangered native birds. Chain of love is a classic example of an invasive plant that poses a serious threat to all the island's flora.

Summary

The history of Guahan can be summarized by the examples of the following plants. Endemic orchids and seeded breadfruit or *dokdok* were among the early and unique plants to develop on the island (Table 1). Birds and waves brought the seeds of indigenous plants, such as beach mahogany or *da'ok* and iron wood or *gagu* (Table 2). Chamorro voyagers carried taro or *suni*, yam or *dagu,* breadfruit or *lemmai,* banana or *chotda,* coconut or *niyok*, and, most intriguing, rice or *fa'i* to the island shores (Table 3). Spanish colonists introduced many fruits and vegetables, such as chile pepper or *donne'* and pineapple or *pina* (Table 4). Americans brought in *tangantangan* to reforest the WW II battle fields, but is now a wide spread, invasive weed tree (Table 5). Chain of love or *kadena de amor* is an aggressive, invasive vine that now threatens many of the plants described in this paper.

Tables

Table 1. Endemic plants or plants unique to Guahan and neighboring Mariana Islands.

COMMON	CHAMORRO[2]	SCIENTIFIC[3]
seeded breadfruit	*dokdok*	*Artocarpus mariannensis*
torch wood	*gaosali*	*Bikkia tetrandra*
coral tree	*gaogao*	*Erythrina variegata*
pandanus	*kafo'*	*Pandanus tectorius*
wild orchid	*siboyas halomtano*	*Bulbophyllum guamense*

[2] Topping
[3] Raulerson

Table 2. Indigenous plants or plants naturally distributed in the western Pacific Islands before the arrival of humans.

COMMON	CHAMORRO[4]	SCIENTIFIC[5]
iron wood	*gagu*	*Casuarina equisetifolia*
beach hibiscus	*pagu*	*Hibiscus tiliaceus*
vesi	*ifet*	*Intsia bijuga*
Indian mulberry	*ladda*	*Morinda citrifolia*
tropical almond	*talisai*	*Terminalia catappa*
rosewood	*banalu*	*Thespesia populnea*
beach heliotrope	*hunek*	*Tournefortia argentea*
half flower	*nanasu*	*Scaevola taccada*
beach mahoganay	*da'ok*	*Calophyllum inophyllum*
banyan	*nunu*	*Ficus prolix*

[4] Topping
[5] Elevitch

Table 3. Plants brought to Guahan by ancient Chamorro voyagers.

COMMON	CHAMORRO[6]	SCIENTIFIC[78]
coconut	*niyok*	*Cocos nucifera*
banana	*chotda*	*Musa* species
breadfruit	*lemmai*	*Artocarpus altilis*
taro	*suni*	*Colocasia esculenta*
yam	*dagu*	*Dioscorea alata*
rice	*fa'i*	*Oryza sativa*
sugar cane	*tupu*	*Saccharum officinarum*
betel nut	*pugua'*	*Areca catechu*
pepper leaf	*pupulu*	*Piper betel*
ginger	*hasngot*	*Zingiber zerumbet*

[6] Topping
[7] Falanruw
[8] Elevitch

Table 4. Plants introduced to Guahan during the Spanish colonial ear.

COMMON	CHAMORRO[9]	SCIENTIFIC[10]
chile pepper	*donne'*	*Capsicum annuum*
corn	*mai'es*	*Zea mays*
pineapple	*pina*	*Ananas comosus*
papaya	*papaya*	*Carica papaya*
sweet potato	*kamuti*	*Ipomea batatas*
cassava	*mendioka*	*Manihot esculenta*
avocado	*alageta*	*Persea Americana*
lipstick plant	*achoti*	*Bixa orellana*
ylang-ylang	*ilang ilang*	*Cananga odorata*
watermelon	*chandia*	*Citrullus lanatus*

[9] Topping
[10] Falanruw

Table 5. Plants introduced to Guahan during the American administration.

COMMON	CHAMORRO[11]	SCIENTIFIC[12]
monkey pod	*tronkon mames*	*Samanea saman*
---------	*tangantangan*	*Leucaena leucocephala*

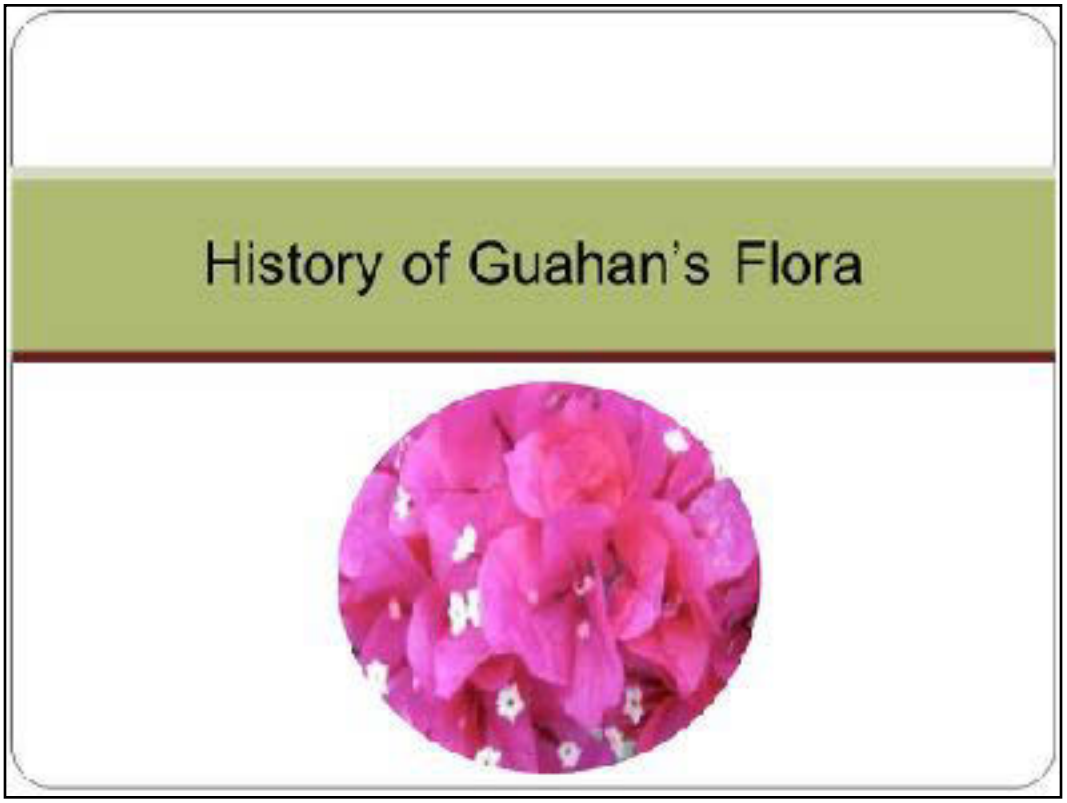
[11] Topping
[12] Elevitch

Table 6. Invasive plant species on Guahan.

COMMON	CHAMORRO[13]	SCIENTIFIC[14]
chain of love	*kadena de amor*	*Antigonon leptopus*
---------	*tangantangan*	*Leucaena leucocephala*
beggar's tick	----	*Bidens alba*
wild or dwarf poinsettia	----	*Euphorbia heterophylla*
sleeping grass	----	*Mimosa pudica*
Jamaica vervain	----	*Stachytarpheta jamaicensis*
African tulip tree	----	*Spathodea campanulata*
Misson grass or fox tailed grass	----	*Pennisetum polystachion*
guinea grass	----	*Panicum maximum*
Siam weed	*masigsig*	*Chromolaena odorata*

[13] Topping
[14] Reddy

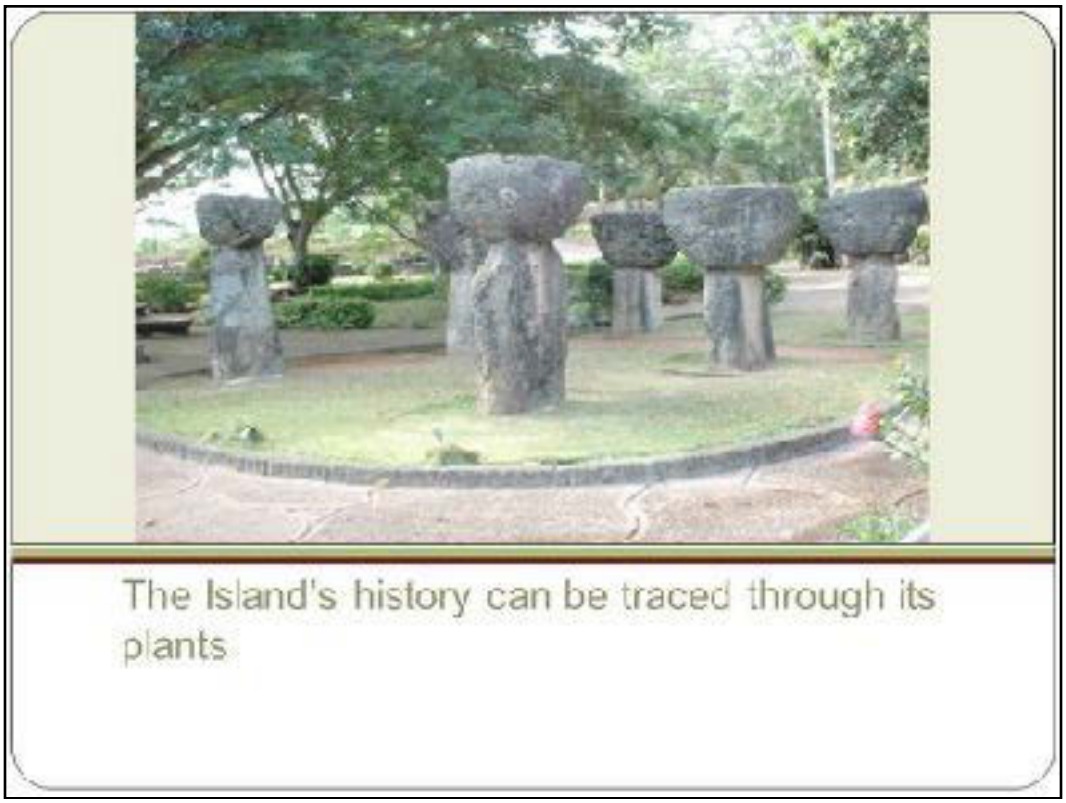
Presentation Slides



Robert F. Bevacqua, PhD
Science Teacher
Guam High School
2013

Western Pacific

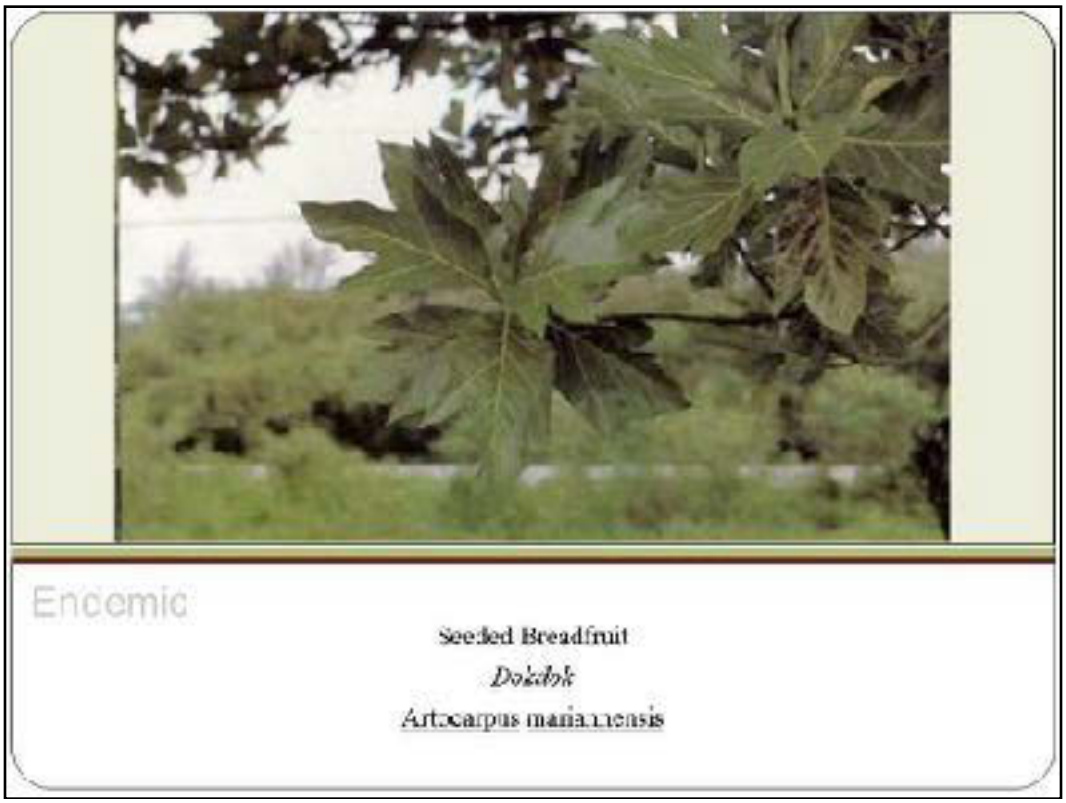
Location of Guam

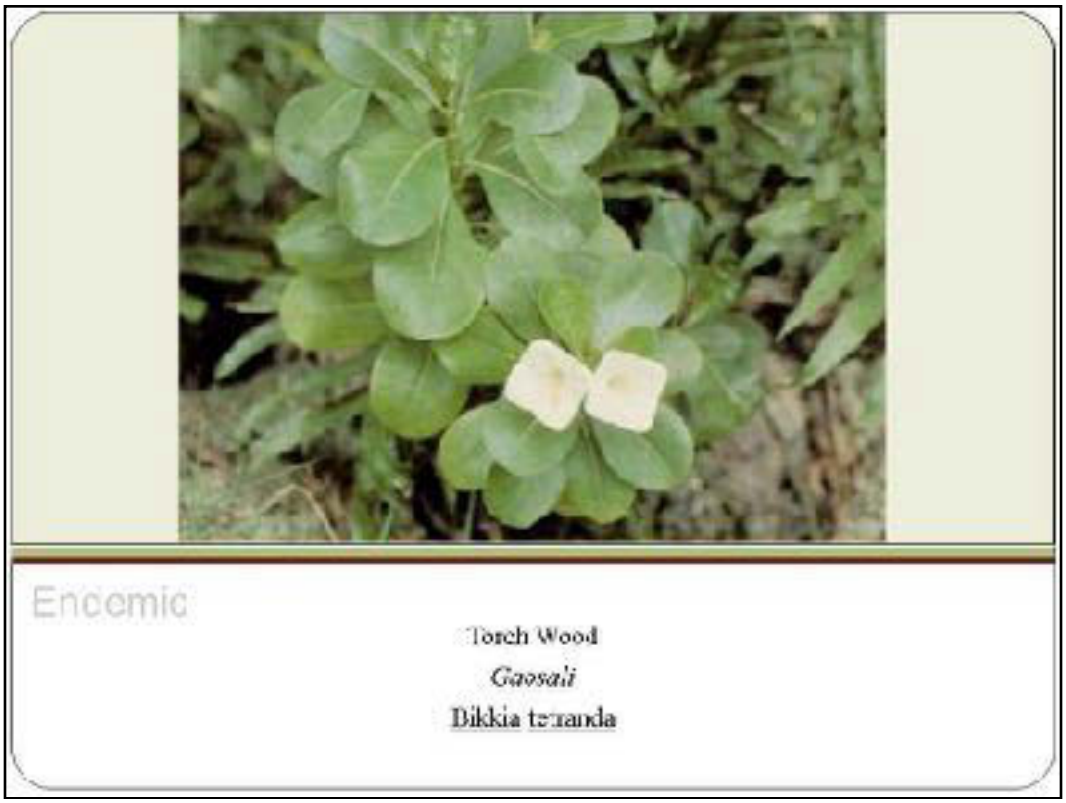


Vocabulary

- Endemic
- Indigenous
- Introduced
  - Chamorro
  - Spanish
  - American
- Invasive


Endemic


Endemic
Seeded Breadfruit
Dokdok
Artocarpus mariannensis

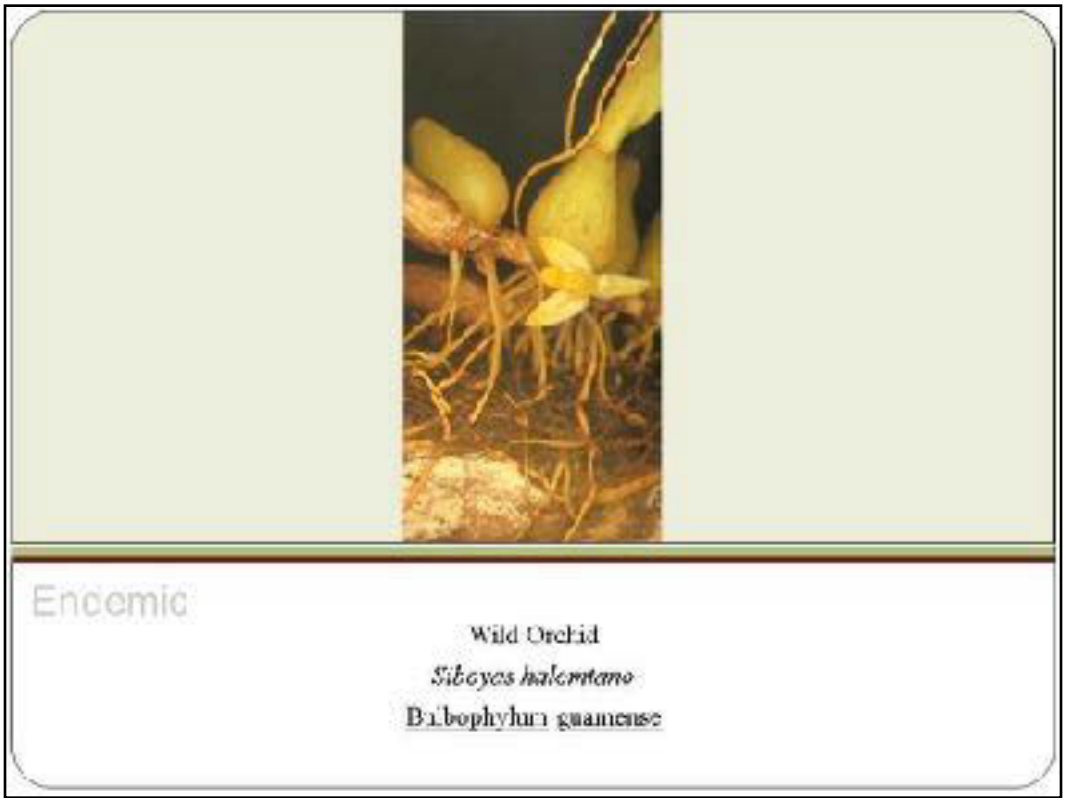


Endemic

Torch Wood

Gaosali

Dikkia tenanda



Endemic

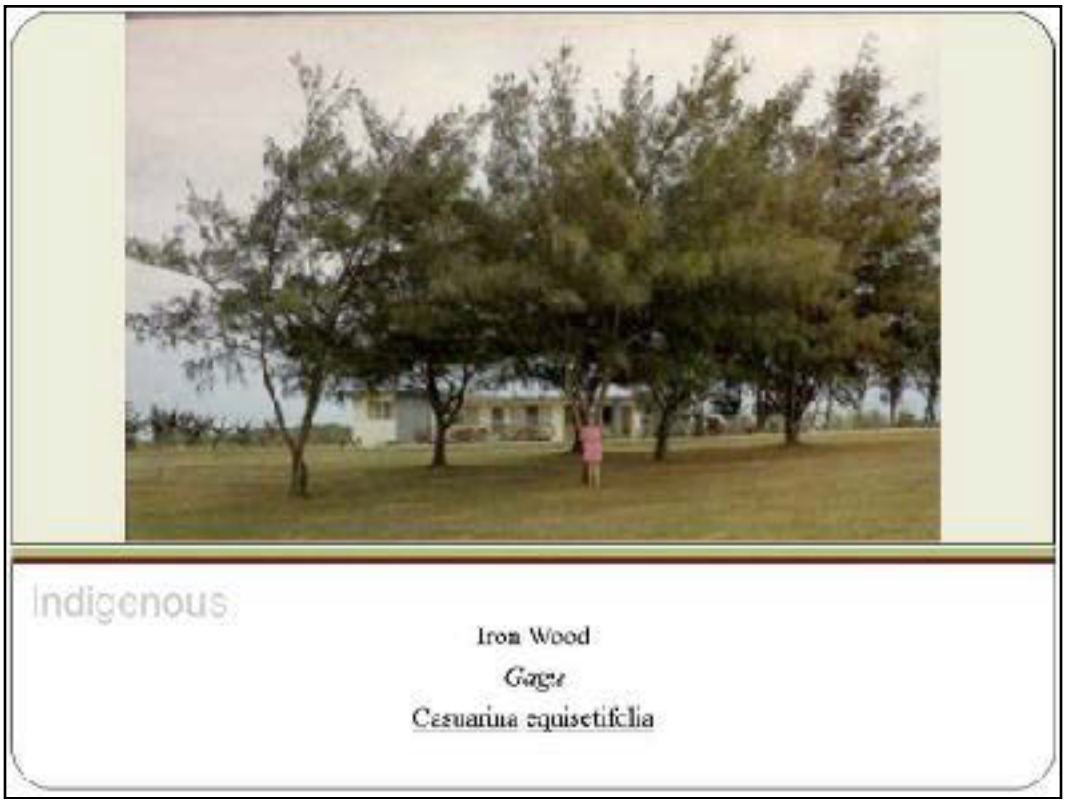
Wild Orchid

Sibcyes halcrntano

Bulbophyhm guamense


Indigenous


Indigenous
Cycad or Fecerico Nut
Fadang
Cycas circinalis

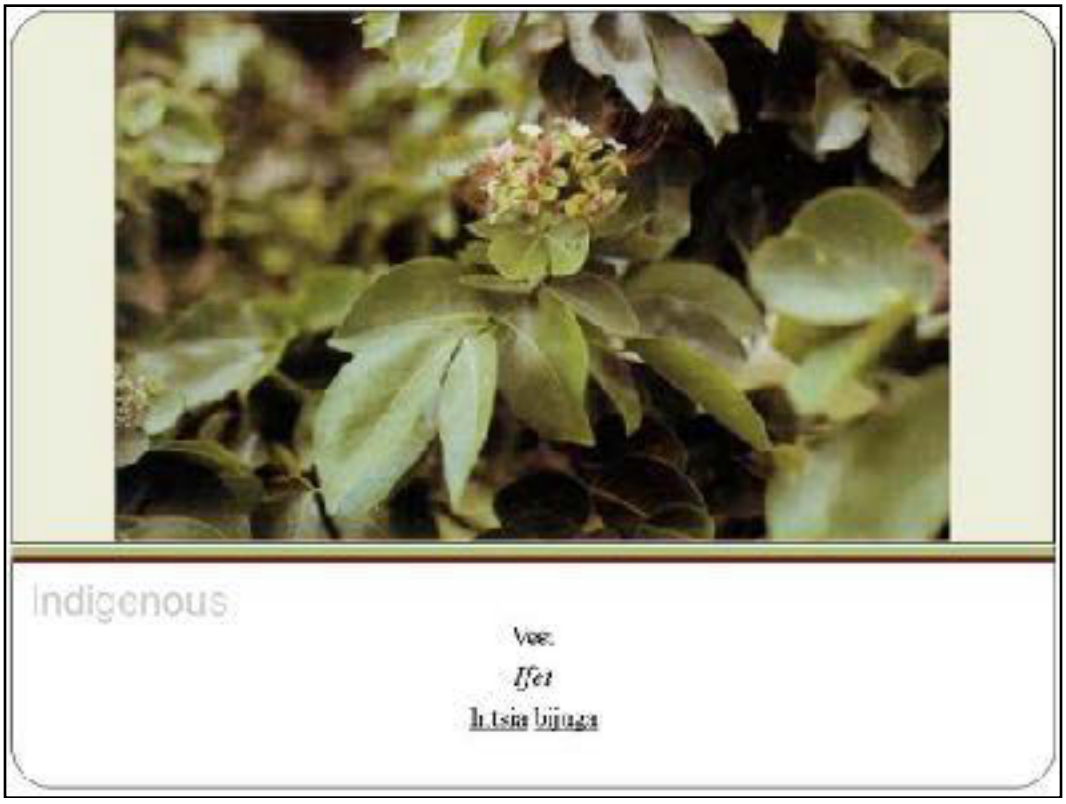


Indigenous

Iron Wood

Gagu

Casuarina equisetifolia



Indigenous

Vine

Ifet

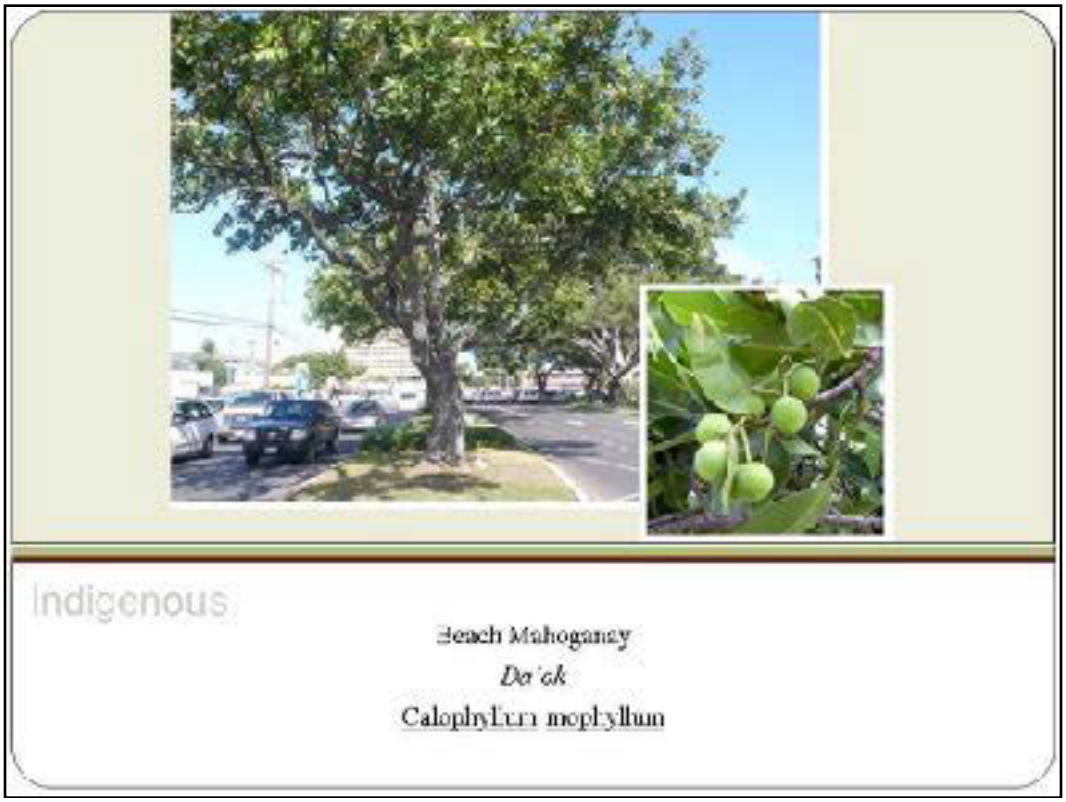
Intsia bijuga

Indigenous

Half Flower

Nanum

Scaevola taccada



Indigenous

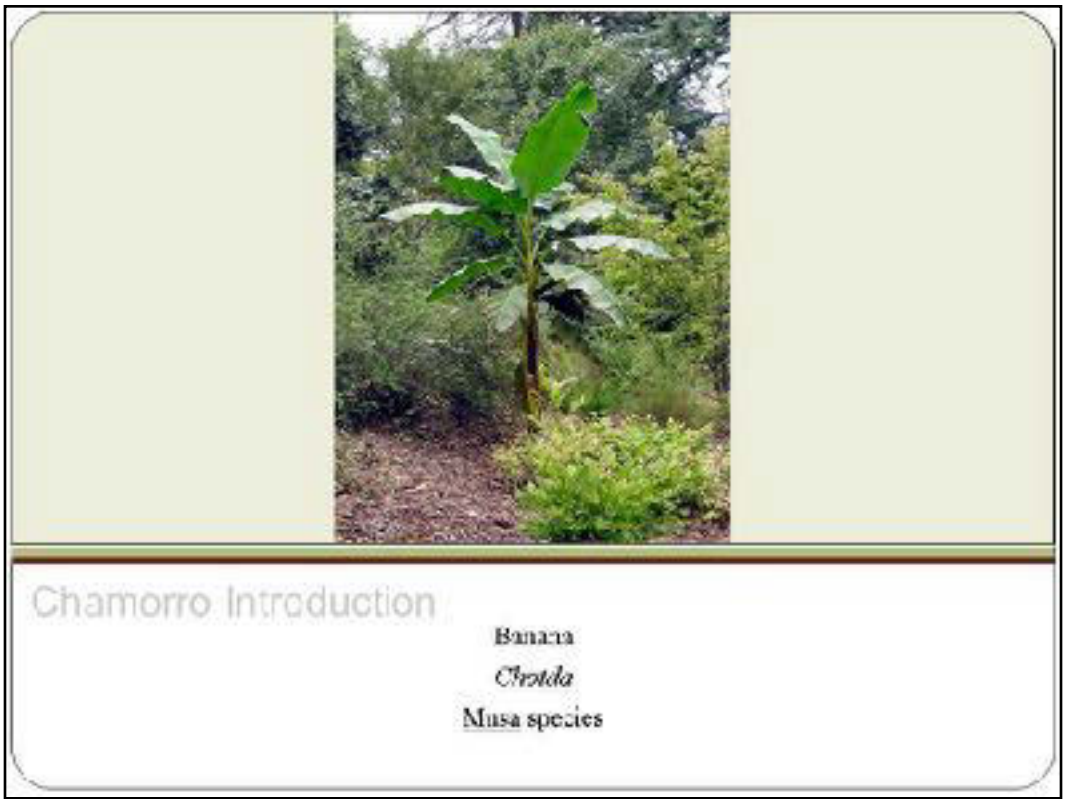
Beach Mahogany

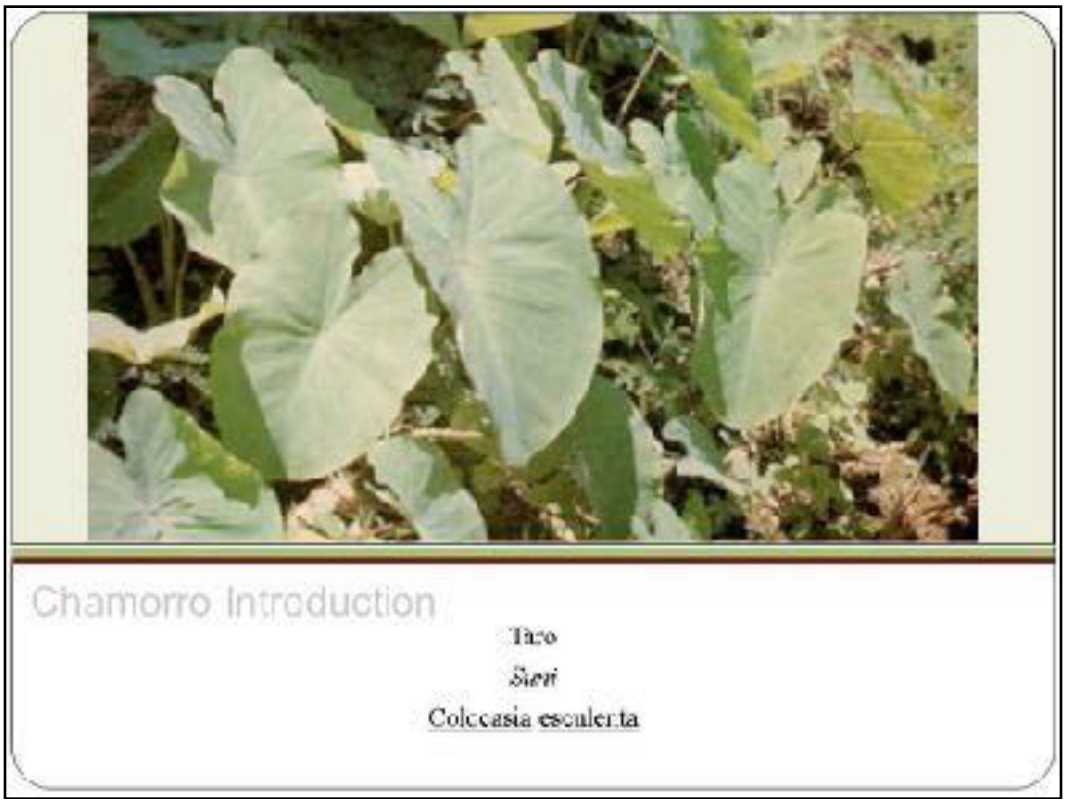
Da'ok

Calophyllum inophyllum


Chamorro Introduction

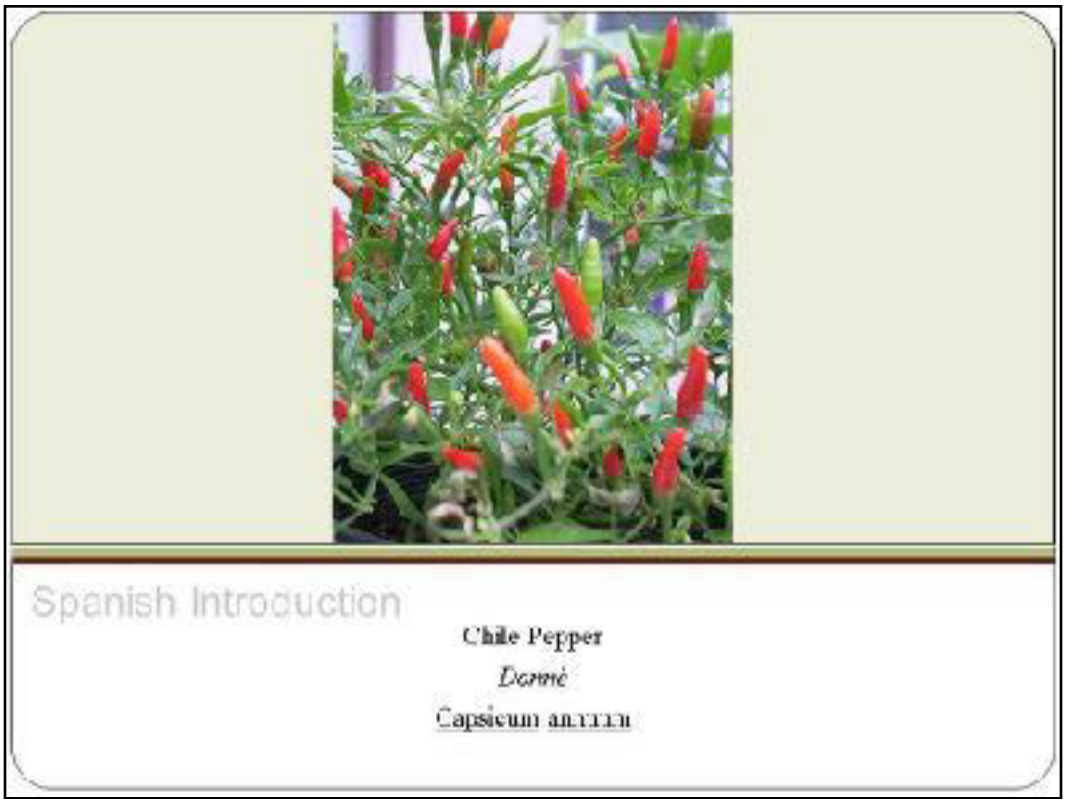

Chamorro Introduction
Coconut
Niyok
Cocos nucifera

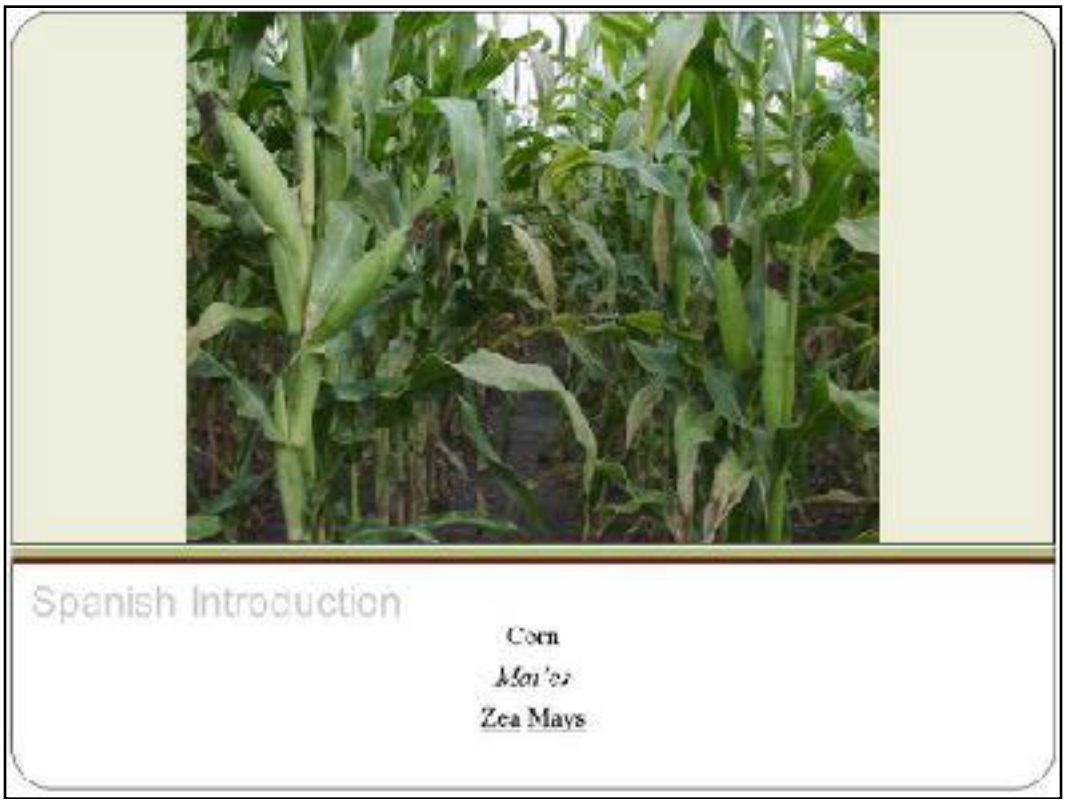

Chamorro Introduction
Banana
Chotda
Musa species


Chamorro Introduction
Taro
Suni
Colocasia esculenta

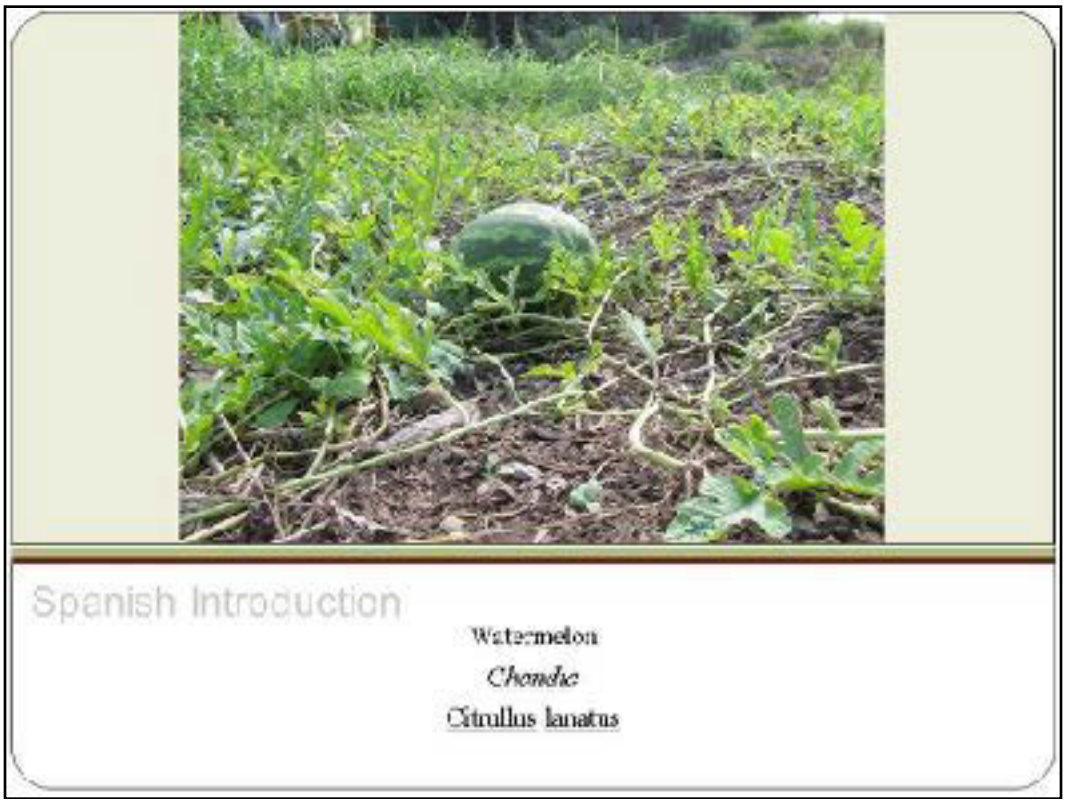

Chamorro Introduction
Rice
Fa'i
Oryza sativa

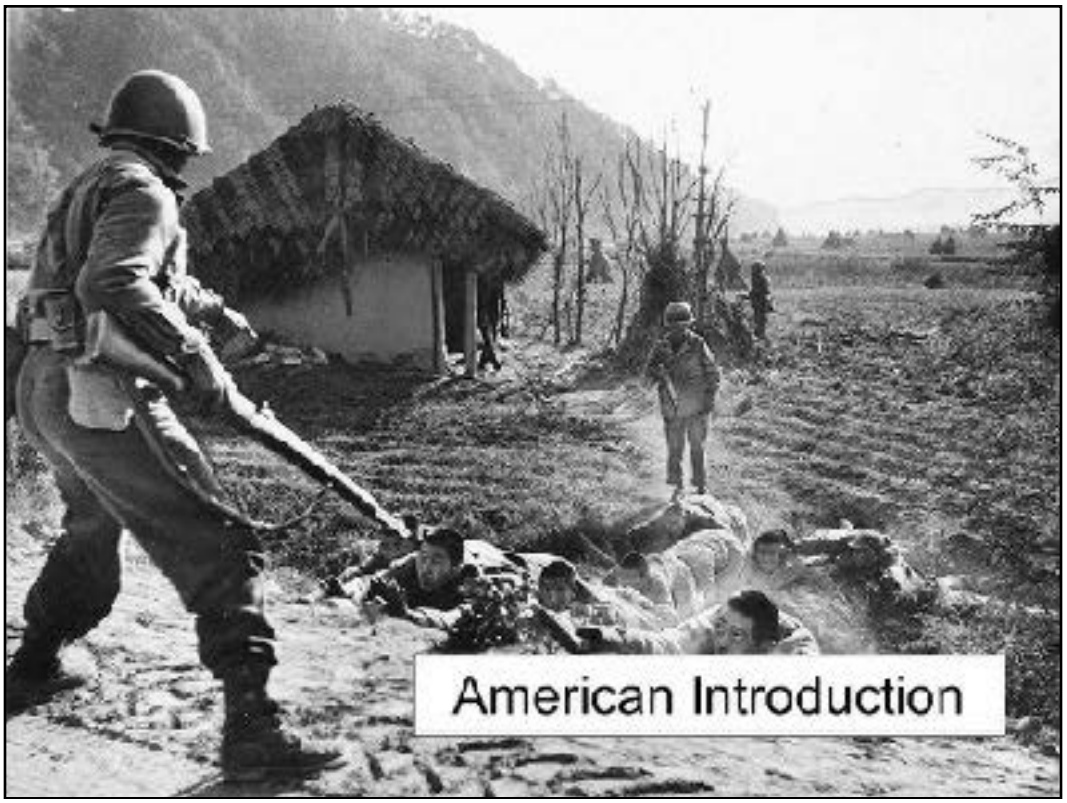

Spanish Introduction

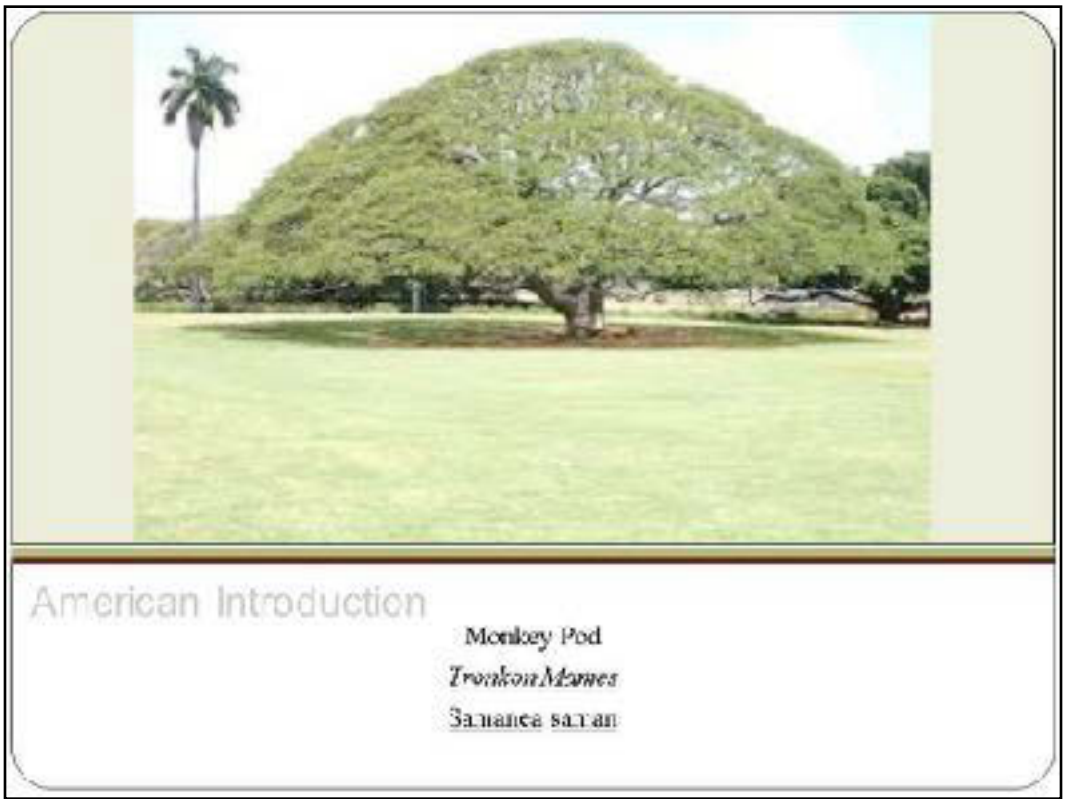

Spanish Introduction
Chile Pepper
Dorné
Capsicum annum


Spanish Introduction
Corn
Mo'o
Zea Mays


Spanish Introduction
Pineapple
Piña
Ananas comosus

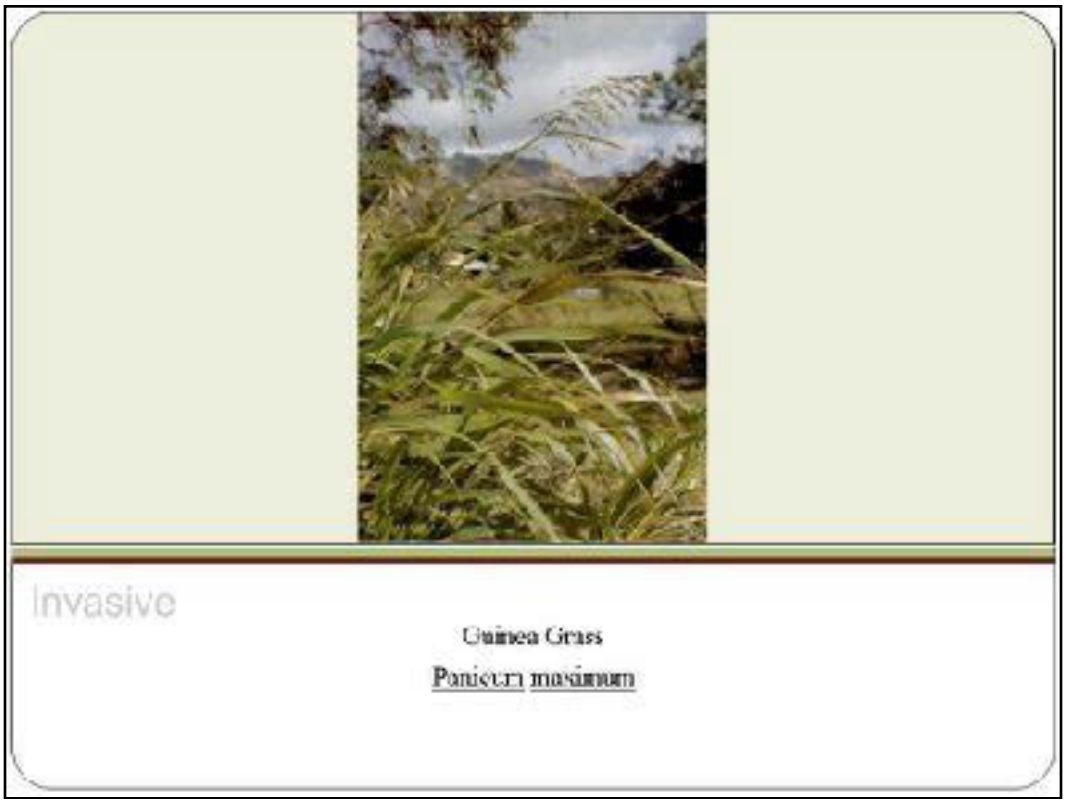

Spanish Introduction
Watermelon
Chomdic
Citrullus lanatus


American Introduction


American Introduction
Monkey Pod
Samanea saman


Invasive

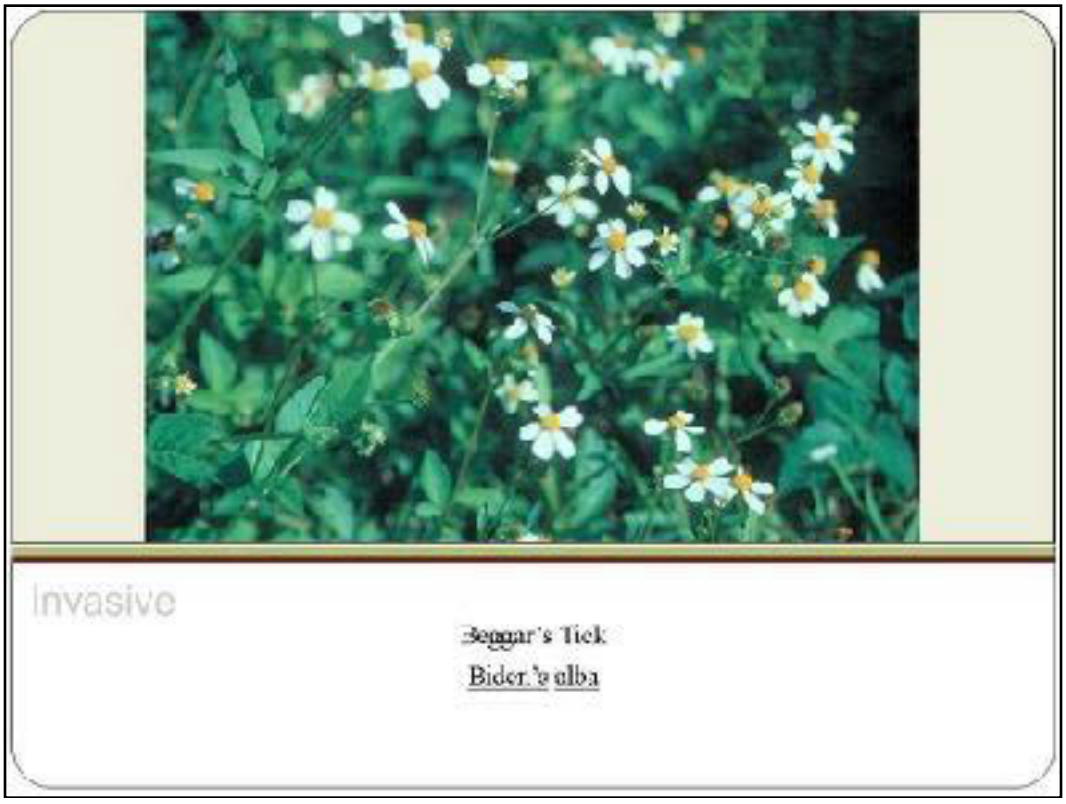

American Introduction/Invasive
Tangantangan
Leucaena leucocephala



Invasive

Guinea Grass

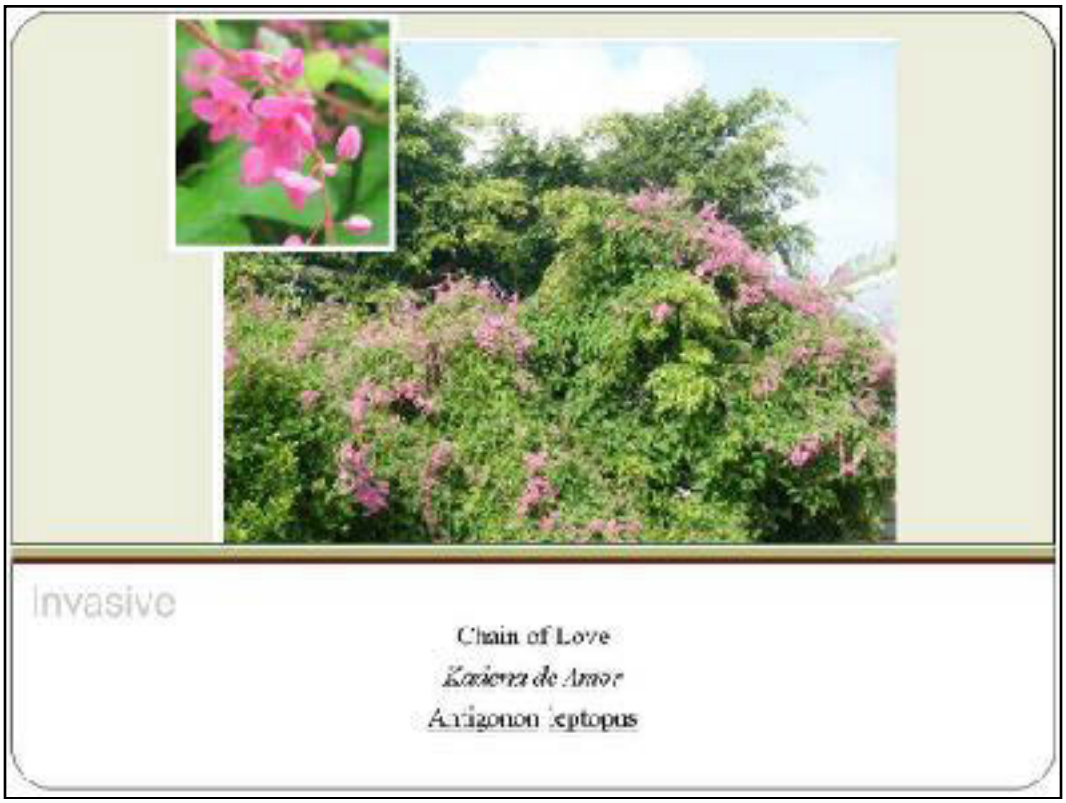
Panicum maximum



Invasive

Beggar's Tick

Bidens alba



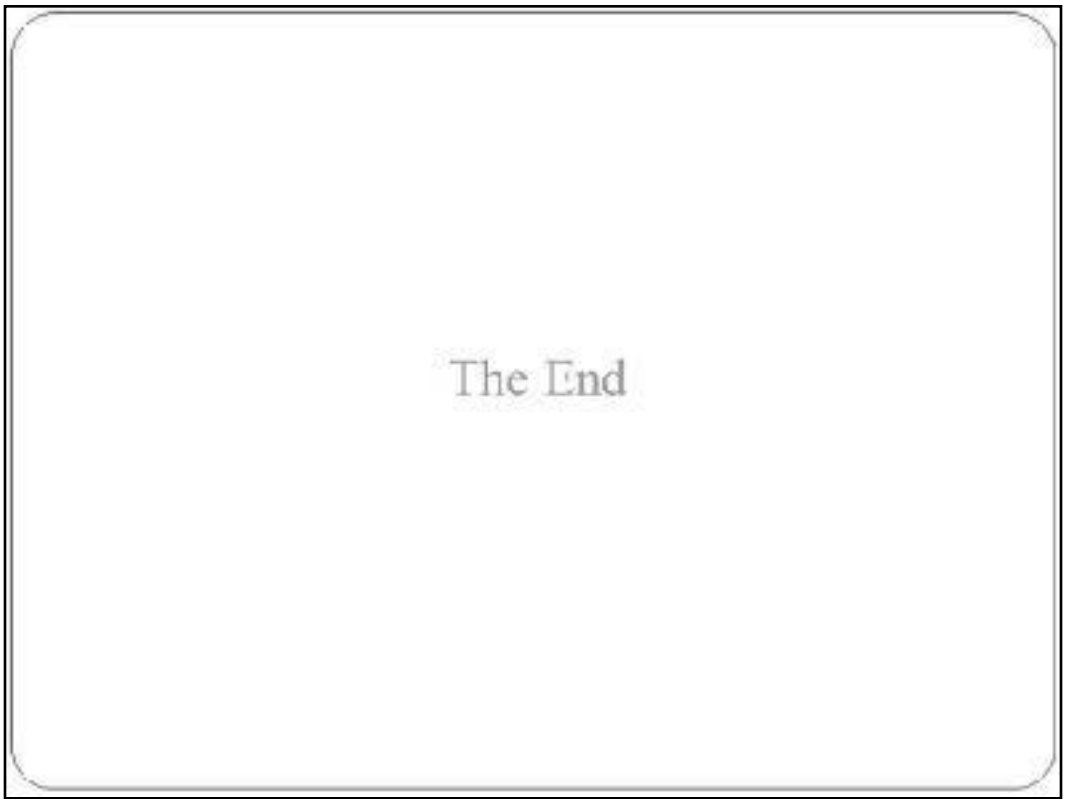
Summary of Guahan's history as traced through its plants:

- Endemic
- Indigenous
- Introduced
  - Chamorro
  - Spanish
  - American
- Invasive

This slide show was prepared by Bella Oviedo,
a freshman at University of Guam.

Acknowledgements

Many of the plant pictures are from 'Plants of Guam', a publication by F. Moore and P. McMakin that was later developed as a webpage at UOG by J. McConnell.



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Robert Bevacqua is a horticulturist with 20 years of experience, including five at UOG, working with tropical fruit and vegetable crops. His experience includes work with US-AID programs in Africa and Asia, the Hawaiian pineapple industry, and cooperative extension (agricultural) programs in Guam, Oregon, California, Virginia, and New Mexico. At present, Dr. Bevacqua is semi-retired and is employed as a science teacher at Guam High School where he teaches biology, chemistry, and marine biology and serves as an athletic coach. He is active in professional development programs for teachers.

Birth-Month Seasonality and the Secondary Sex Ratio in Guamanian Amyotrophic Lateral Sclerosis and Parkinsonism-Dementia Complex

Implications for Infectious Disease and Environmental Etiologie

By Vince P. Diego, PhD[1] and Frank A. Camacho, PhD[2]

[1]Department of Genetics, Texas Biomedical Research Institute
[2]Biology Program, College of Natural and Applied Sciences, University of Guam
vdiego@txbiomedgenetics.org and dr.frank.camacho@gmail.com

Abstract: *Guamanian amyotrophic lateral sclerosis and Parkinsonism-dementia complex (ALS-PDC), which took place primarily over the period from 1950 to 1980, remains a mystery to this day. Incidence rates for the neurological syndrome by birth-year and birth-month were analyzed by periodic regression. The data were best fit by a yearly 2-phase periodicity model over the year ($p < 0.0001$ for the harmonic coefficients; R-squared = 0.12 and 0.25 for the first and second phases, respectively), which reasonably corresponds to two peaks in water availability on Guam. Data on the secondary sex ratio (SSR), defined as the ratio of male to female live births and considered to be an indicator of environmental stress, were also analyzed. The SSR mean for the affected cohort was found to be significantly higher than that for the unaffected cohort ($p < 0.0001$). Taken together, these findings point to an infectious disease or environ-mental toxin etiology.*

Introduction

Shortly after World War II on Guam, there arose an epidemic of amyotrophic lateral sclerosis (ALS) locally known as *lytico* (Koerner, 1952; Arnold et al., 1953; Tillema and Wijnberg, 1953; Kurland and Mulder, 1954a&b; Mulder et al., 1954). Shortly after that, there arose another epidemic that was a complex of Parkinson's disease and dementia (Parkinson's-dementia complex or PDC), locally known as *bodig* (Kurland et al., 1961; Hirano et al., 1961a&b; cf. the earlier observations in this regard in Mulder et al., 1954). Since the work of Kurland, Hirano and colleagues on the underlying neuropathology of these diseases (see also Elizan et al., 1966; Hirano et al., 1966; reviewed and updated in Garruto, 2012), the two diseases have been widely felt to constitute a single neurological syndrome, which is now known as Guamanian ALS-PDC (Galasko et al., 2000, 2002; Plato et al., 2002, 2003). Over the years, many hypotheses have been proposed to explain the epidemic but there is currently no consensus as to which, if any, provides the best overall explanation of all of the observed patterns. (In what

follows, we will use the phrase *lytico* and *bodig* to refer to Guamanian ALS-PDC as it is generally understood. Under this usage for example, when we speak of individuals who succumbed to *lytico* and *bodig* we mean individuals who have succumbed to ALS, PDC, or ALS-PDC as there were some individuals who contracted both diseases.) On the other hand, not one hypothesis has been refuted outright and so they all remain viable explanations, even if unsatisfactory. Rather than review these hypotheses (some of which have been reviewed by Garruto (2012) anyway), we will here focus on resurrecting one of the oldest hypotheses to explain *lytico* and *bodig*, namely the hypothesis of an infectious disease etiology, specifically the viral encephalitis hypothesis (Koerner, 1952; Arnold et al., 1953; Tillema and Wijnberg, 1953; Mulder et al., 1954). Since its initial proposal in the early years of the epidemic, the viral encephalitis hypothesis would resurface time and again (Gibbs and Gajdusek, 1972, 1982; Hudson, 1981, 1991, 1993; Miura et al., 1987; Shimura et al., 1987; Hudson and Rice, 1990; Underwood, 1992; Okumura et al., 1995), but apart from the circumstantial comparative neuropathological evidence provided by Hudson and the evidence on birth-month seasonality provided by Underwood, there has been as of yet little else to support the hypothesis. Here we bolster the viral encephalitis hypothesis by reanalyzing an up-to-date version of Underwood's data, and, in addition, we will also provide some supporting historical evidence that have hitherto not been considered in this light. We reserve the more technical matters of our work to a forthcoming publication, and will focus on developing a generally accessible exposition

Evidence from Seasonality and Secondary Sex Ratio of Guamanian ALS-PDC

From Figure 1, we see that the major part of the epidemic ranges from about just after World War II (WWII) to about the mid-1980s. Given an age-of-onset of about 40 years for the syndrome, Underwood (1992) noted that this time frame for the major part of the epidemic would for the most part correspond to the birth cohort of those born in the interval 1901-1940. As alluded to earlier, Underwood (1992) found evidence of birth-month seasonality in Chamorros who were born in the interval from 1901 to 1940 and who eventually succumbed to *lytico* and *bodig* (cf. Underwood's (1991) finding of birth-month seasonality in mortality for the general population). Some background on the specifics of her study is required here for a better understanding. First, she meticulously constructed a demographic database of Guamanian Chamorros starting with the 1897 census (Underwood, 1990) all the way through to 2011 (Anne K. Underwood, personal communication). From this demographic database, she isolated the individuals who died of *lytico* and *bodig* and grouped them according to their

birth-month. She did this for Chamorros born in the interval from 1901 to 1940 because this birth-cohort

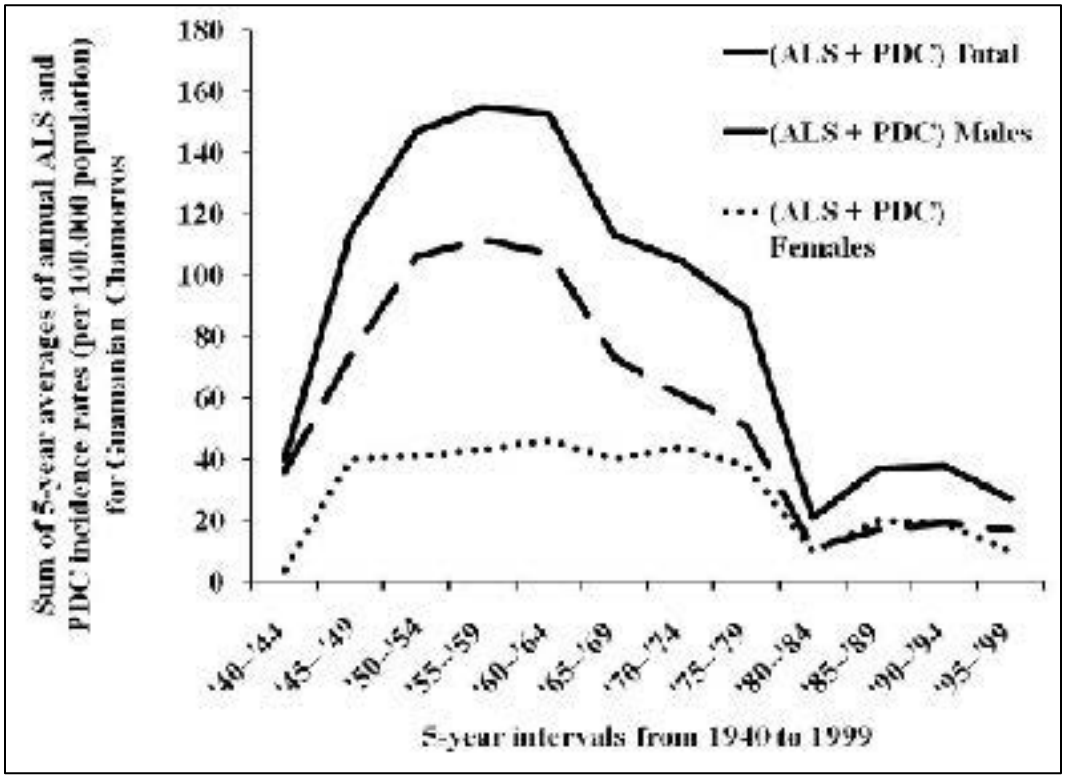


Figure 1. Sum of 5-year averages of annual incidences of Guamanian amyotrophic lateral sclerosis (ALS) and Parkinson's-dementia complex (PDC). Data are from Plato et al., (2003). The curves are not meant to be analytic but mainly to portray the major features of the epidemic. Sum of ALS and PDC: Total (solid line); Males (long-dashed line); Females (dotted line).

corresponds to the cohort of individuals who would come to manifest *lytico* and *bodig* in the peak phase of the epidemic (Figure 1). On comparing the observed annual distribution of births to the expected, she found by a chi-square test that there was significant evidence of birth-month seasonality (Figure 2A). Here seasonality simply refers to the statistically significant tendency for observations to be grouped around a certain part of the year more so than would be expected by chance. We found after analyzing her most recent dataset that the initial seasonality result did not hold up (Figure 2B). This may be due to a "tightening" of disease definitions and associated designation criteria for disease-affectation status as knowledge of the syndrome accrued over time and a consequent re-classification of borderline affected cases to the unaffected status. However, we cannot confirm this because Dr. Underwood was recently deceased.

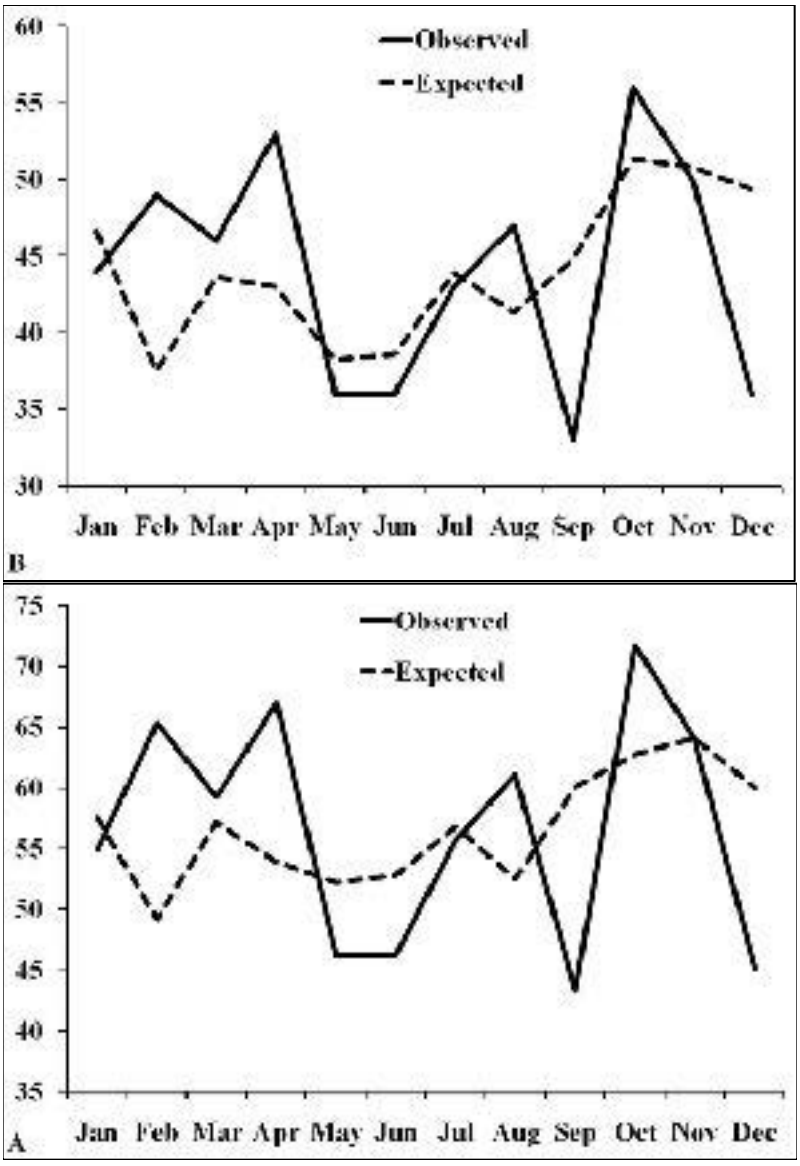


Figure 2. Average monthly incidence of Guamanian amyotrophic lateral sclerosis and Parkinson's over the period 1901-1940 by birth-month. Observed and expected curves are in solid and dashed lines, respectively. A. Re-drawn from data obtained from graphical digital data extraction software applied to Underwood's (1992) Figure 1. B. Computed from Underwood's most up-to-date dataset as of 2011.

Still, we felt that perhaps a more rigorous analysis might shed some light on this issue. For this reason, we performed a periodic regression analysis which essentially fits the terms of a Fourier expansion to the data. A Fourier expansion can be plotted as a periodic sine curve, hence the name periodic or trigonometric regression (Bliss, 1958; Fellman and Eriksson, 2000; Barnett and Dobson, 2010; Shumway and Stoffer, 2011). Because it is still a regression model, we were able to test for seasonality by way of the analysis of variance or ANOVA following Bliss (1958). We found that there was a significant interaction between years and a two-phase periodic regression model. This

result can be understood by referring to the yearly mortality profile of the birth cohort (Figure 3). We see that there are roughly two patterns. For about the first 25 years there was an elevated oscillatory level of mortality reminiscent of an infectious disease epidemic, and then for roughly the last 15 years there was a reduced level of mortality associated with an attenuated oscillation to eventual termination of the epidemic. If there was significant seasonality in the first part of this overall pattern and none in the second part, then it is understandable that we would indeed find an interaction between years and a seasonality signal.

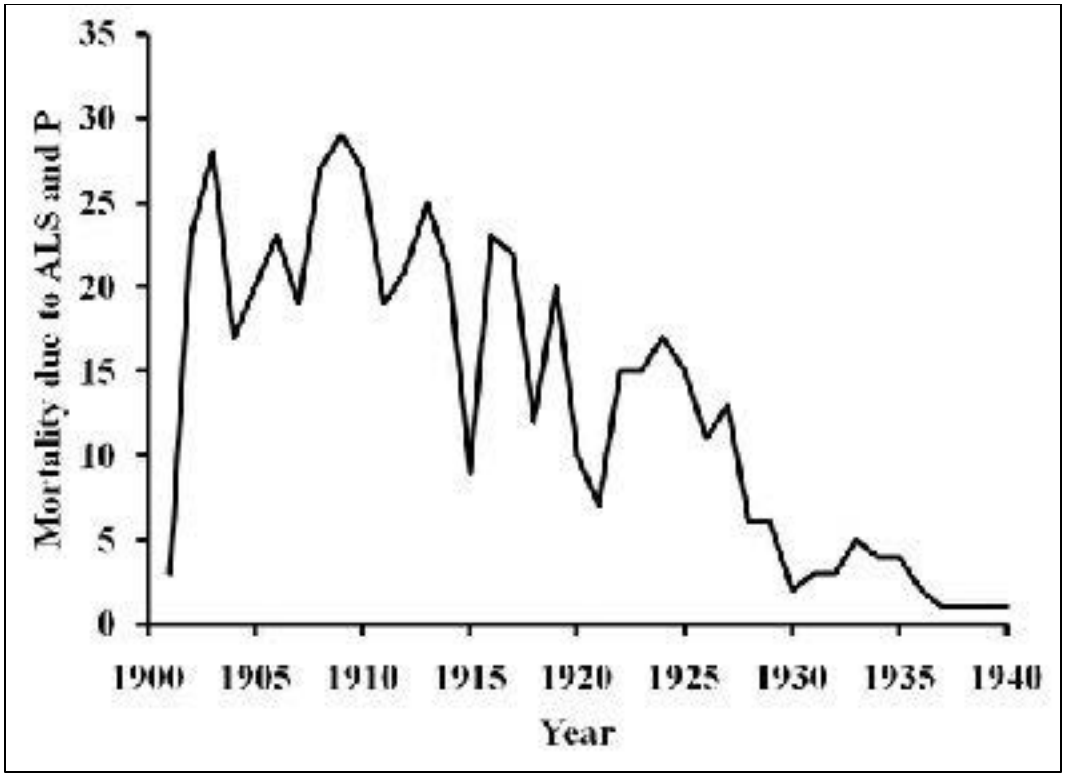


Figure 3. Mortality by birth-year for Guamanian amyotrophic lateral sclerosis and Parkinson's for the period 1901-1940.

Seasonality in the *lytico* and *bodig* mortality data implies some kind of "tracking" of an environmental factor such as rainfall. Thus, we analyzed the relationship between rainfall data for the interval 1909-1939 and the corresponding normalized incidence of *lytico* and *bodig* (Figures 4A-B). We found that there was a significant correlation between both the mean normalized incidence of *lytico* and *bodig* and a 3-year lag in total annual rainfall. Similar relationships were observed between total and mean daily rainfall and the mean normalized prevalence. We will have more to say about this result later on. Moreover, it is noteworthy that when broken up into two temporally

contiguous segments, the correlation between normalized mortality prevalence and rainfall for the first segment is higher than that for the second segment and the variance in normalized mortality prevalence is higher for the first segment than that for the second segment. These patterns are consistent with the periodic regression results. In turn, rainfall seasonality in the mortality data implies some etiological agent that in some way can be said to track rainfall. We suggest that there are at least three such potential etiological agents: 1) infectious disease, 2) minerals in the soil such as aluminum (Garruto, 2012), and 3) cyanobacterial-toxin-enhanced bioavailability of aluminum (Miller and Sanzolone, 2003). While these are equally viable hypotheses on the seasonality results alone, the historical data presented below would seem to favor the infectious disease hypothesis.

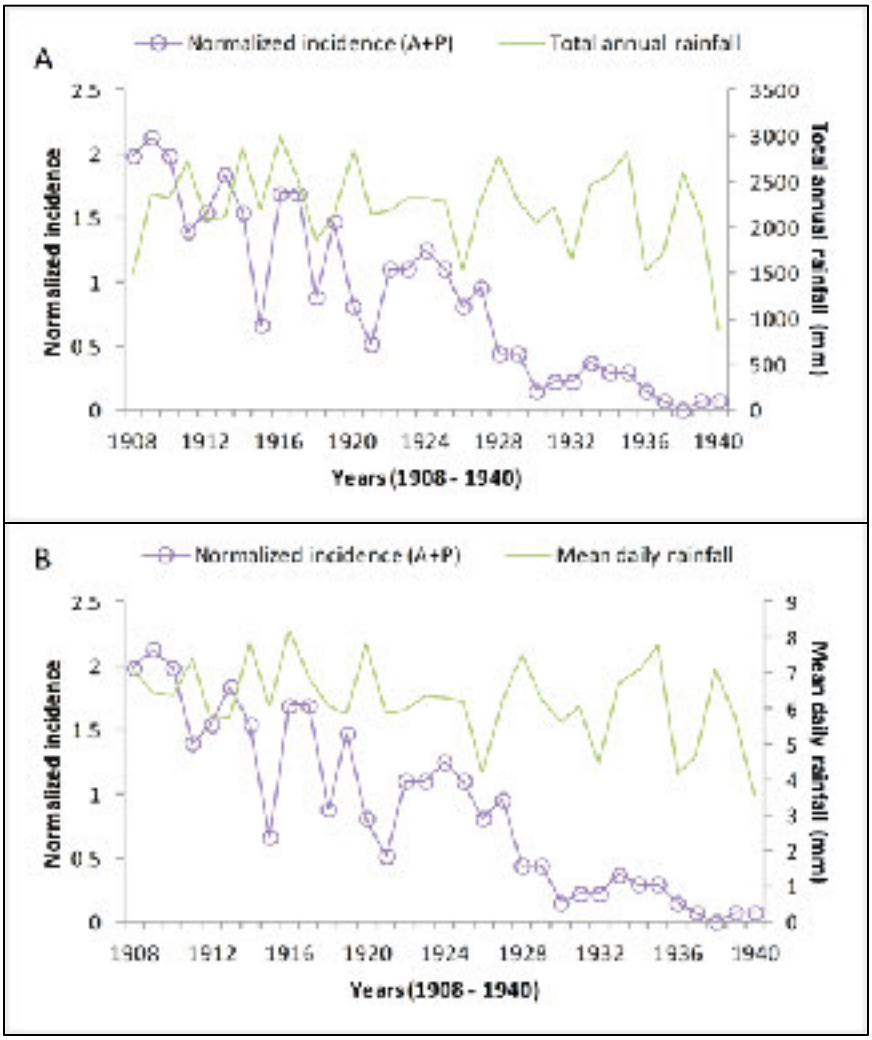


Figure 4. Mean normalized incidence of ALS and PD versus (A) total annual rainfall (mm) and (B) mean daily rainfall (mm) for the years 1908 - 1940. Statistical analyses were restricted to the years 1909 - 1939 as these years comprised the most complete records of the rainfall dataset for Guam. Rainfall data are from Kubota and Chan (2009).

A third line of evidence that would seem to support an infectious disease etiology comes from our analysis of the secondary sex ratio (SSR), here defined as the ratio of males to females at birth after Underwood (1994). The SSR can help us to better ascertain the probability of an environmental derived etiology because it is well-known to be an indicator of environmental stress, especially as it relates to mortality and morbidity in early childhood (Mathews and Hamilton, 2005). From chi-square analysis of the SSR for affected and unaffected individuals (affected and unaffected SSR, respectively), we found that the affected SSR is significantly higher than the unaffected SSR. More to the point, by breaking up the 40 year block for the birth cohort (i.e. from 1901 to 1940) into five- and ten-year periods, we found that the elevated signal for the affected SSR holds only for the first half of the 40 year block, which is consistent with both the periodic regression and rainfall correlation analyses. The elevated affected SSR is a crucial observation, we believe, because of the robust pattern of a male-biased mortality and morbidity due to infectious disease (Shettles, 1958; Washburn et al., 1965; Goble and Konopka, 1973; Green, 1992; Klein, 2000, 2004, 2005, 2012; Fish, 2008; Guerra-Silveira and Abad-Franch, 2013).

To sum up this section, three complementary lines of evidence point to an infectious disease etiology of *lytico* and *bodig*. The two main specific infectious diseases that have been suggested under this hypothesis are encephalitis due to JEV and encephalitis due to the polio virus, the virus that causes poliomyelitis.

Before proceeding to the next section, we note here that another important observation is in regard to the regional geography of the syndrome epidemic. In particular, *lytico* and *bodig* incidence and prevalence was highest in Southern Guam, especially in Umatac, and in Rota (Reed et al., 1966; Reed and Brody, 1975).

Bio-Historical Evidence for Japanese Encephalitis Virus (JEV) and for Poliomyelitis

Japanese encephalitis virus

There are three lines of evidence that support the hypothesis that JEV is the etiological agent of *lytico* and *bodig*: 1) The occurrence of an outbreak of JEV from 1947 to 1948 at the beginning of the *lytico* and *bodig* epidemic (Hammon et al., 1958); 2) A serological study on the prevalence of antibodies to JEV demonstrating prevalent inapparent JEV infection in general, inapparent infection is also known as sub-clinical infection or infection not requiring clinical attention mainly in Southern Guam and prevalent JEV infection in domesticated animals that may serve as a reservoir (Hammon et al., 1958); and 3) Entomological surveys demonstrating that the

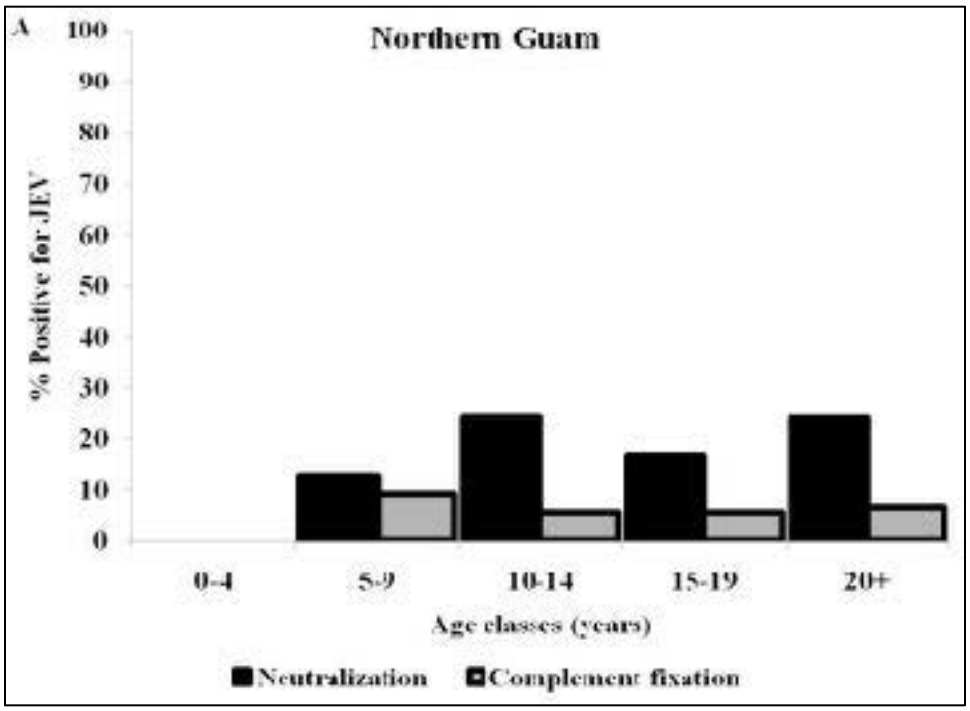
mosquito vector of JEV was prevalent during the appropriate time period on Guam from the early 1900s up to the 1947-1948 JEV epidemic (Fullaway, 1912, 1913; Swezey, 1942; Knight et al., 1944; Reeves and Rudnick, 1951; Nowell, 1976) and quite possibly on Rota (Bohart and Ingram, 1946; Bohart, 1956; Nowell and Sutton, 1977).

Regarding the first line of evidence, in fact Mulder et al. (1954) noted that one patient who contracted *bodig* had survived the JEV outbreak. Further, Hammon (1953) reported that he had isolated JE virus from brain tissue samples from two individuals who died of encephalitis over the course of the epidemic. However, Hirano et al. (1961) in interviews with patients and their relatives specifically about any history of encephalitis in the patient's medical history found that no one could remember such events. Obviously, this "negative evidence" would seem to detract from the poliomyelitis hypothesis as well. The complete lack of any kind of clinical history regarding encephalitis is consistent, however, with the hypothesis of inapparent infection postulated by T. Miura and colleagues (Miura et al., 1977; Miura, 1987; Miura et al., 1987; Shimura et al., 1987; cf. the discussion in Shimura et al. (1987) which shows that this hypothesis has often been postulated by other investigators for other neurological disorders). Under said hypothesis, it is possible for individuals to experience bouts of inapparent infection early in life that would eventually give rise after some indeterminate period of latency to clinical disease later in life. A corollary of the hypothesis of inapparent infection holds that, just as infections can give rise to epidemics, inapparent infections can give rise to inapparent epidemics (Miura, 1987). This idea of an environmental stressor experienced early in life that eventually gives rise to a neurological disease later in life has been proposed in general (Liu et al., 2003; Landrigan et al., 2005; Logroscino, 2005) and in regard to *lytico* and *bodig* in particular (Calne et al., 1986; Eisen and Hudson, 1987; Garruto, 1996) and so it is not at all an outrageous idea. We note here that this counter-argument applies to the poliomyelitis hypothesis just as well and will take it up again when we discuss the evidence for it.

The age distribution of JEV infection is significant here. Data from different sources indicate that the peak incidence of JEV infection is in children 3 to 6 years of age (Vaughn and Hoke, 1992; Endy and Nisalak, 2002; Halstead and Jacobson, 2003). This age distribution of JEV infection provides a mechanism for generating the correlation of *lytico* and *bodig* mortality with a 3-year lag in rainfall mentioned earlier.
The second line of evidence dovetails nicely with the previous line in that the single-most compelling empirical finding for the general hypothesis of inapparent infection

is the fact that for many infectious diseases a large percentage of a given population can be seropositive for the infection and yet not have any overt manifestation of disease or clinical history in this regard (cf. a similar argument in Miura (1987)). In fact, it has been noted that for JEV infections the ratio of clinical cases to asymptomatic infected cases ranges from 1:50 to 1:1000 (Vaughn and Hoke, 1992; van den Hurk et al., 2009; Turtle and Solomon, 2013). That is, for every clinical case there can be anywhere from 50 to 1000 infected individuals who do not manifest frank disease. This was ostensibly the case for JEV on Guam. We hasten to add that this was found to be the case in Japan (Miura et al., 1977; Miura, 1987). In Figure 5A&B, we present the results from the seroepidemiological study by Hammon et al. (1958) on normal individuals (i.e. apparently healthy individuals) from Northern and Southern Guam. As is readily understood on comparing the numbers for Northern and Southern Guam, individuals from Southern Guam have greater levels of inapparent infection ($p << 0.01$ by a one-tailed paired t-test for both assays). That is to say such individuals were clearly infected with JEV and yet were deemed normal by trained physicians in this case. Further, the prevalence of inapparent infection would seem to favor the view that JEV had been endemic on the island for quite some time. Indeed, this is how Hammon (1953: 342) interpreted these results in his report of JEV on Guam and other Pacific areas: "Of particular interest . . . is the finding that the sera of numerous normal natives gave results indicating that infection with Japanese B encephalitis virus [the older name for JEV] had been experienced by some at least a year and possibly many years prior to this recognized outbreak."

Before we move on, we note that the differential geographic distribution fits that for *lytico* and *bodig* exactly in that the southern villages, especially Umatac, Agat, Merizo, and Inarajan, were differentially affected by the syndrome. Further still, given that JEV is one of those peculiar viruses that not only has a dead-end human host and a mosquito vector but also a large reservoir of animal species that it can infect and survive in, Hammon et al. (1958) also tested a number of animal species. They found that most of the domesticated animal species save for cats and chickens harbored JEV (Figure 5C).


A
Northern Guam
% Positive for JEV
100
90
80
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Age classes (years)
Neutralization
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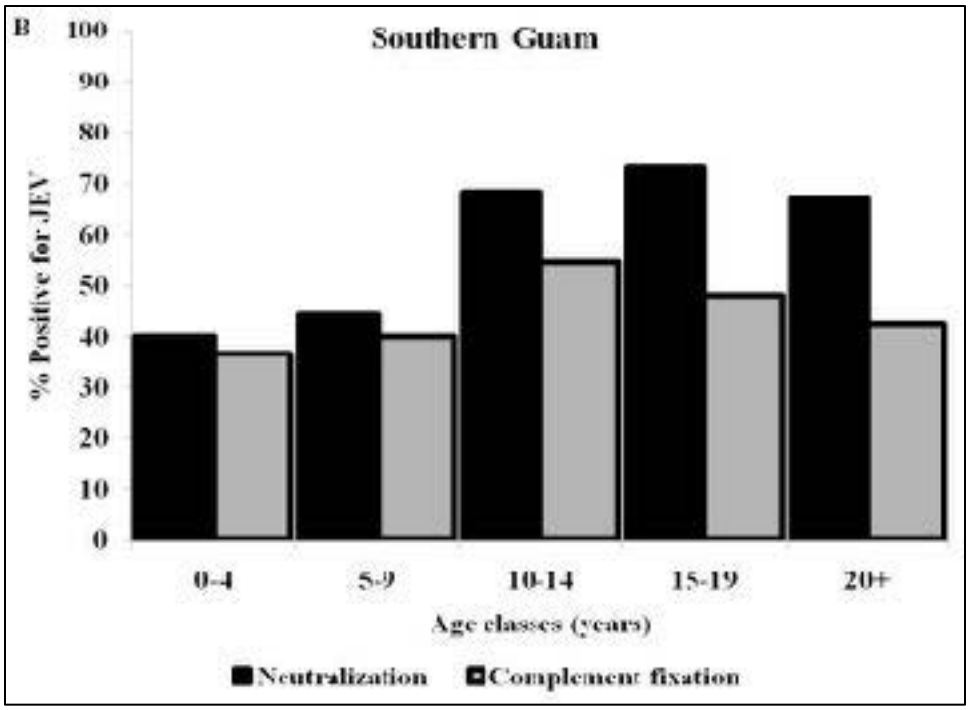
B
Southern Guam
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100
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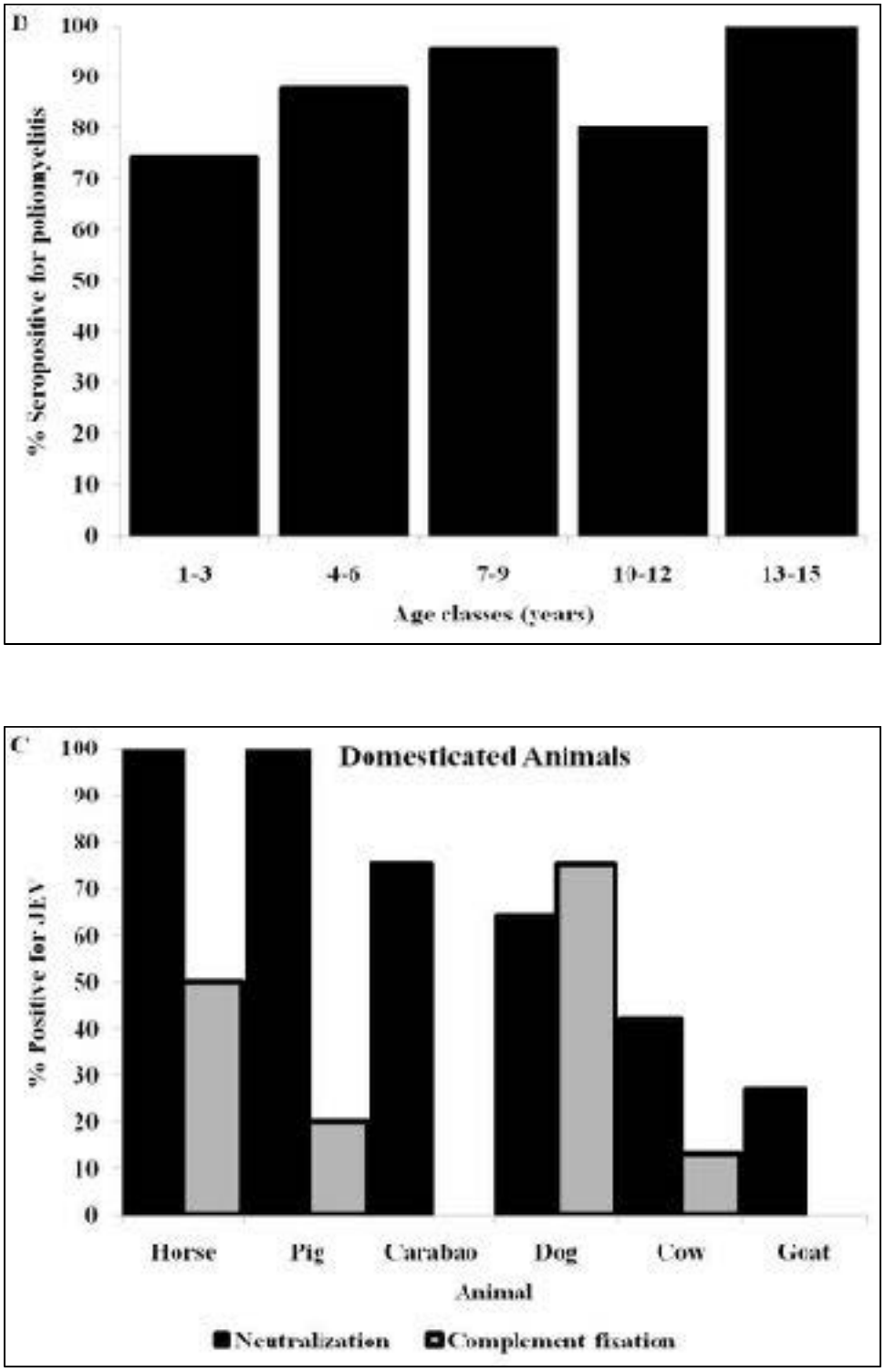

Figure 5. Serological data for Japanese encephalitis virus (JEV) infection on Guam from Hammon et al. (1958) and for poliomyelitis on Guam from Hammon et al. (1950). A-D: Antibody neutralization assay (black columns). A-C: Complement fixation assay (dark gray columns). A. Results for JEV infection on Northern Guam. B. Results for JEV infection on Southern Guam. C. Results for for JEV infection in domesticated animals. D. Results for poliomyelitis infection in children on Guam.

As just mentioned, JEV requires a mosquito vector for transmission to humans and thus if JEV is to be causal for *lytico* and *bodig* its mosquito vector must be present on Guam and Rota in sufficient numbers for the hypothesis to be viable. It turns out that this is the case as well. Fullaway (1912, 1913) reported that a mosquito, *Culex* sp. near *vishnui*, was found on Guam as early as 1911, although Swezey (1942) and Nowell (1976) believed this to be *C. quinquefasciatus*. This is significant because either species, but especially members of the *vishnui* subgroup, are JEV vectors (Vaughn and Hoke, 1992; Endy and Nisalak, 2002; Halstead and Jacobson, 2003; van den Hurk et al., 2009). Bohart and Gressit (1951) noted that *C. quinquefasciatus* preferentially bred in polluted water on Guam (cf. Bohart, 1956). Moreover, Bohart (1956) noted that *C. quinquefasciatus* are severe pests at night. After the 1947-1948 JEV epidemic on Guam, Reeves and Rudnick (1951) carried out an extensive mosquito survey on the island. They found that at least two of the mosquito species known to be JEV vectors were prevalent. Of these, Hammon et al. (1958) suggested that *C. annulirostris marianae* was the vector responsible for the JEV epidemic. It is noteworthy, therefore, that Ward (1984) considered this species to be endemic to the Marianas. As for Rota, several members of the genus *Culex*, *C. quinquefasciatus* in particular, were found to be present at least as of 1945 (Bohart and Ingram, 1946; Bohart, 1956; Nowell and Sutton, 1977).

In extensive tests for encephalitis viruses (20,361 mosquitoes across six species to be exact), Reeves and Rudnick (1951) found no evidence of virus. From the perspective of a proponent of the JEV hypothesis this negative finding is also not too much of a problem for two reasons. The first reason is that JEV has a complex transmission cycle in which it annually cycles through its animal hosts, mosquito vectors, and human hosts and depending on which part of the cycle the virus is in it can be completely absent from its mosquito vectors for part of the year (Vaughn and Hoke, 1992; van den Hurk et al., 2009). In fact, in the seminal studies on the ecology of the JEV transmission cycle by Buescher and Scherer (1959), it was noted that the virus was undetectable for about a quarter of the year from April through late June. We assert that this had to be the case or something like this on Guam because the serological data from Hammon et al. (1958) were from blood samples collected in 1948 (based on the dates for the tables from which the data were extracted, specifically their Table 6 on page 454 and Table 9 on page 455 for Northern and Southern Guam, respectively) and the entomological data from Reeves and Rudnick (1951) were collected roughly around the same time from 1948 to 1949. These data were collected roughly contemporaneously! There is an interesting parallel case from Okinawa. Tigertt et al. (1950) were unable to find evidence of JE virus in vector mosquitoes collected in

Okinawa just after the JEV epidemics there from 1945 to 1949. The second reason why the negative finding of no encephalitis viruses in mosquitoes is not a problem for the JEV hypothesis is that the principal part of the geographic range for JEV is Southeast Asia (Vaughn and Hoke, 1992; Endy and Nisalak, 2002; Halstead and Jacobson, 2003; van den Hurk et al., 2009; Turtle and Solomon, 2013) and as is well known there has historically been significant ship traffic between Southeast Asia and Guam. Hornbostel (1925) observed that mosquitoes, although not necessarily JEV vectors, were inadvertently transported to Guam in the water tanks of whaling ships. Similarly, when he discussed the source of JEV infections, Hammon (1953: 345) wrote, "[w]e must recognize, therefore, that infected men, infected animals, and infected arthropod vectors can be transported by ship and plane, making further spread of this serious epidemic disease a real problem of concern to all tropical and temperature [sic; presumably temperate] Pacific areas, both eastern and western." Moreover, Mackenzie et al. (2004, 2006) noted that relatively recent JEV epidemics in Western Oceania were probably initiated by wind-blown infected mosquitoes and/or infected birds. Thus it is not beyond reason to expect a not infrequent re-introduction of JEV to the island by ship travel, wind-blown infected mosquitoes and/or infected birds should it ever be completely absent for a time.

Poliomyelitis

We now turn to the hypothesis that poliomyelitis is the causal etiological agent of *lytico* and *bodig*. There are several sources of historical evidence that make the poliomyelitis hypothesis attractive, and we will find shortly there is also strong supporting serological evidence rivaling that for JEV (and in fact obtained by the same principal investigator, W. McD. Hammon). Our arguments start with the arrival of the steamer the El Cano at Guam in 1899 shortly after the Spanish-American War (Figure 6). The El Cano arrived at Guam having traveled from Manila with about 700 passengers (Driver and Brunal-Perry, 1998: 111). Further, we find from American Naval medical officers at the time that a poliomyelitis epidemic had started on Guam shortly after and was probably due to, it was thought, the El Cano's arrival (presumably due to the passengers of course) (Grunwell, 1900; Leach, 1900; Safford, 1905; McCullough, 1908). We find similar information from the translation of Spanish documents in Driver and Brunal-Perry (1998). In their translation, we find the report made by the Spanish priest and Vicar Provincial of the Marianas Francisco Resano of an influenza epidemic and associated information, such as symptoms, point of origin and the beginning of the epidemic (Driver and Brunal-Perry, 1998: 112-114). Based on tell-tale symptoms related by Father

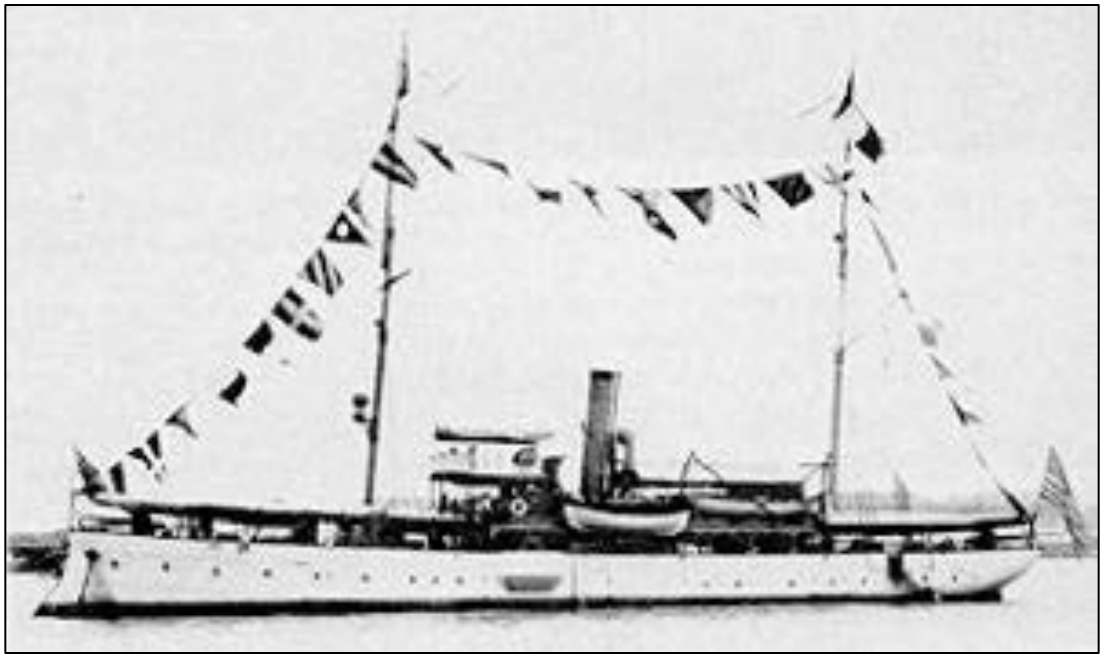

Figure 6. The El Cano steamer. The ship was originally a Spanish vessel built in 1885, but was captured by the U.S. in the Battle of Manila Bay, May 1, 1898 during the Spanish-American War. Source: Dictionary of American Naval Fighting Ships, Vol. II p 334 available on-line at: http://www.hazegray.org/danfs/patrol/pg38.htm. Photo source: NavSource online; available at: http://www.navsource.org/archives/12/09038.htm

Resano such as victims stiffening (p. 112), pain in the bones that produced rigidity (p. 113), pain in the neck, spine and waist (p. 113), and difficulty or inability in swallowing and breathing (p. 113), combined with the medical opinions of Leach and Grunwell, and based on the common (to all three reports, that is) point of origin and beginning of the epidemic, we conclude that the influenza epidemic reported by Father Resano was in fact the poliomyelitis epidemic reported by Leach and Grunwell. This is a key observation because we will now take it as established that Father Resano's account was in regard to the poliomyelitis epidemic. Thus, it is extremely significant that when still writing of the epidemic he made the following statement:

> On 13 June of this year, 1899, Father Ildefonso Cavanillas and Father Crisogono Ortín, the priests of Agat and Merizo, came to bid farewell and receive their orders to embark for Manila or directly for Spain via Hong Kong. Once the arrangements for their departure were made, **they returned to their pueblos where many were sick**. Driver and Brunal-Perry (1998: 112) (italics in original; boldface ours; pueblo is defined as a village in the book)

Further, we know in another translation of Spanish documents from the same time period by Driver (2000: 12-15) that at the time Merizo was composed of Merizo proper and Umatac. This is confirmed by a footnote in McGrath (1989) regarding similar Spanish documents and by Safford (1905: 137, Table 1) when he reported the results of the 1901 census for Guam in which he listed Merizo (proper) and Merizo (district of Umatag [sic]). Further still, on page 60 in Driver (2000) we find that Father Ortín is described as the priest of Merizo and Inarajan. When put all together this information would seem to imply that practically all of Southern Guam from Agat south to Umatac and Merizo and then to Inarajan was severely affected by the poliomyelitis epidemic. Still talking about the epidemic on page 114 of Driver and Brunal-Perry (1998), we find another important report by Father Resano: "On . . . June, Harrison's schooner arrived from Japan. He had come via Saipan and **Rota and brought us the news that the same illness prevailed in the northern islands** (boldface ours)." This observation is important because, under the poliomyelitis hypothesis, it establishes a causal link between poliomyelitis and the *lytico* and *bodig* cases in Rota.

Before delving into the serological evidence, we need to revisit the earlier discussion on inapparent infection. It turns out that poliomyelitis exhibits a striking parallel to JEV in this respect, although it is a waterborne infection as opposed to mosquito-borne. According to Atkinson et al. (2012), as high as 95% of all polio infections are inapparent! Similar to JEV, the ratio of clinical cases to inapparent cases of polio infection ranges from 1:50 to 1:1000, with the usual ratio being 1:200 (Atkinson et al., 2012). With this knowledge, it is therefore not too surprising that Hammon and colleagues found on the basis of serological studies that polio infection was practically endemic in Guam, especially in children (Hammon, 1949, 1951; Hammon et al., 1950; Hammon and Sather, 1953). In Figure 5D, we report the serological results for antibodies to poliomyelitis from Hammon et al. (1950). It is perhaps best to let Hammon himself interpret these results. To this end, we use to quotes from Hammon (1951):

> It will be recalled (table 1 [cf. our Figure 5D]) that over 50% of the infants on Guam are infected before the first birthday and paralytic disease is not observed there. However, according to a very complete report made by a visiting American naval medical officer in 1900 [referring to Grunwell, 1900], a disease fitting closely the clinical syndrome of paralytic poliomyelitis attacked a large portion of that isolated population, but paralytic cases occurred chiefly in the age groups above 15 years and spared the very young. **We might postulate**

> **that since that apparent introduction of virus by a trading ship it has spread rapidly during infancy, and the population has remained free from paralytic disease through early immunization**. (boldface ours; p. 744)
>
> We have drawn further indirect evidence from epidemiologic reasoning about the apparent persistence of poliomyelitis virus on the island of Guam, where rubeola, pertussis, epidemic parotitis and other solidly immunizing infections have died out repeatedly and required reintroduction by visitors. Streptococcal and diphtherial infections appear to remain present there and **evidence suggests that poliomyelitis must have remained similarly, probably through reinfection of immunes who became inapparent carriers**. (boldface ours; p. 746)

It is clear from these statements that Hammon envisioned a scenario of prevalent inapparent poliomyelitis infection in the Guamanian population in the critical time frame of 1900 up until the time of his work there in 1948. This work received some attention in the national press as Figure 7 demonstrates. Note also Hammon's comments in these news articles as they pertain to the idea of inapparent infection.

New Polio Immunity Theory Advanced by Medical Report

BERKELEY, Cal. — (U.P.) — A University of California professor advances a new concept on the process of immunity in polio.

Dr. W. M. Hammon, professor of epidemiology, and the concept is the result of studies made with March of Dimes funds and is detailed in full in the September issue of Bacteriological Reviews.

Polio, Dr. Hammon pointed out, generally is considered to be one of those diseases in which permanent immunity is acquired following infection but accumulating evidence is supporting the idea that the immunity is transitory.

Dr. Hammon placed polio in the same class as diphtheria and scarlet fever . . . "In the case of these two diseases, it is recognized that persons who have been infected can become convalescent and can be the source of infection for others even though they previously have shown some immune response in standard tests."

"The reinfected person may not become ill, but he does become a healthy carrier," he said.

If further evidence bears out the new theory, there will be important public health implications, the professor added. Persons show by tests that they have had polio, even though not of the crippling variety, may face quarantine if they have contact with an active case.

In advancing the new concept, Dr. Hammon cited several studies, including recent work he did on the island of Guam.

"After the war there were outbreaks of measles and mumps. Less than a year ago an outbreak of polio occured . . . polio acted like the streptococcal infections, not like those in which permanent immunity is acquired," he said.

Dr. Hammon also reported preliminary results of an attempt to determine at what age polio is contracted in various parts of the world. The scientist said that early results indicate the disease is acquired earlier in the tropical Pacific island of Guam than in the northern United States.

He said on Guam polio antibodies showed up in 50 per cent of the children at one year of age while in San Francisco, 50 per cent did not show previous infection until 10 to 11 years of age.

POLIO IMMUNITY MAY BE TEMPORARY

SAN FRANCISCO—Immunity to polio, acquired by contracting the infection, may be temporary rather than permanent, as has been supposed.

This is the conclusion of a study made with March of Dimes funds by Dr. W. McD. Hammon, noted epidemiologist in the University of California's Hooper Foundation.

POLIO HAS BEEN classed with the measles and mumps so far as immunity is concerned, the infection in each case bestowing permanent immunity. Dr. Hammon suggests instead that polio may be in the same immunological class as diphtheria and streptococcal infections, in which immunity is transitory.

The scientist bases his theory, including his study of a polio outbreak on Guam less than a year ago. At that time polio appeared among the white children of American dependents, but it did not show up among the native Guamanians.

There has never been evidences of polio among the Guamanians. Dr. Hammon said. Why, then, did it not appear among the Guamanian children, who would be presumed to have no immunity?

Tests of the blood of Guamanian children gave the answer when they showed that every child from one to four years of age had been infected with polio at one time or another!

DR. HAMMON'S reconstruction of this strange situation is something as follows: In very young children, polio is seldom crippling and usually not severe. So it is probable that polio has always been underground on Guam. Immunity is acquired very young, the disease passing as a bad cold or similar infection, and is bolstered from time to time by reinfection from underground reservoir. So when the disease appeared among the whites, the Guamanians were unaffected.

On the other hand, when measles and mumps were introduced to the island, all natives—children and adults alike—who had not had the diseases were afflicted. Measles and mumps then burned themselves out when everyone had contracted the disease, unlike polio which lives on.

Figure 7. Left panel: Article from the Eugene Register Guard, September 18, 1949, p. 2B. Right panel: Article from the St. Petersburg Times, October 9, 1949, p. 55.

Both etiological hypotheses in relation to the sex ratio in *lytico* and *bodig*

As can be readily perceived from Figure 1, one of the more obvious and important patterns exhibited by the syndrome epidemic is that the male-to-female sex ratio in incidence is higher than would be expected by chance if the syndrome affected the sexes equally or, alternatively, if the sexes responded equally to the syndrome. In fact, at its highest the sex ratio was 3:1 males to females. Obviously, any etiological hypothesis must be able to explain this pattern. It happens that both the JEV and poliomyelitis hypotheses can easily account for this pattern because males tend to be infected at a higher rate relative to females. In a recent review of JEV by Tiwari et al. (2012), it was noted that the male-to-female ratio of infection ranges from about 1.5:1 to 2:1. Presumably because poliomyelitis is nearing global eradication there does not seem to be any reviews to our knowledge that quote a sex ratio. However, based on our analysis of over 50 epidemiological reports of poliomyelitis over the period 1887-1987 from around the world we found that the maximum likelihood estimate (under a binomial likelihood model) from these data of the male-to-female ratio is about 1.5:1, with a ratio of 3:1 within the range of statistical variation (Park and Park, 1986). Thus, inapparent epidemics of either could in theory easily generate the male-biased sex ratio observed for *lytico* and *bodig*.

Discussion and Conclusions

The epidemic of *lytico* and *bodig* in the Marianas remains unsolved to this day. However, we believe that we have uncovered compelling evidence that supports an infectious disease etiology, either of JEV and/or poliomyelitis. Further, it is also possible that both infectious diseases were involved in a unified etiological model, which we call a two-hit model. Under this two-hit model, we hypothesize that poliomyelitis would have delivered the first hit followed by JEV delivering the second hit. This order is supported by their respective age distributions of infection. Polio infection is known to affect the very young (below 3 years of age) as well as older ages in childhood whereas JEV is most prevalent in children in the age range of 3 to 6 years of age. This model could be generalized to a multi-hit model where other environmental insults deriving from aluminum, cycad toxins, and cyanobacterial toxins would compound a pre-existing progression towards frank *lytico* and *bodig*. Whatever the precise combination of environmental insults may be, we believe that infectious diseases, particularly poliomyelitis and Japanese encephalitis, occurring early in childhood on Guam and Rota would have been the main etiological movers.

Acknowledgements

We dedicate this article to the memory of Dr. Jane Hainline Underwood, (1931-2011). We thank Drs. Gary Heathcote and Alex Kerr for numerous correspondences with them. We also thank Dr. Don Rubinstein for help with references, especially the "Chronicle of the Mariana Islands". VPD also thanks Dr. Ralph Garruto for his expert guidance concerning *lytico* and *bodig*.

Presentation Slides

Dedicated to the memory of
Dr. Jane Hainline Underwood, (1931-2011)

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Jane's scholarship was nothing short of exemplary. She was meticulous, doggedly ethical, utterly trustworthy, and knew precisely what she valued and wanted to do. She woke everyday excited to work, and was often in her office before dawn. Jane's retirement project began as a compilation of demographic data of Chamorros listed on the 1897 census of Guam. Over the years it evolved into a truly massive historical reconstruction of over 40,000 linked people, which she updated daily as she followed their births and deaths.

--Obituary in Anthropology News (October 2011)

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In an e-mail letter from Jane's daughter, Anne Underwood, to me and Dr. Gary M. Heathcote :

Vince/Gary –

My mom has requested that I send each of you a copy of her latest Guam Databases. I have imported them into MS Access and created a CD. The data she has entered is up to May 20, 2011.

Sent 6/21/2011

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Some Background on Guamanian ALS-PDC or Lytico and Bodig

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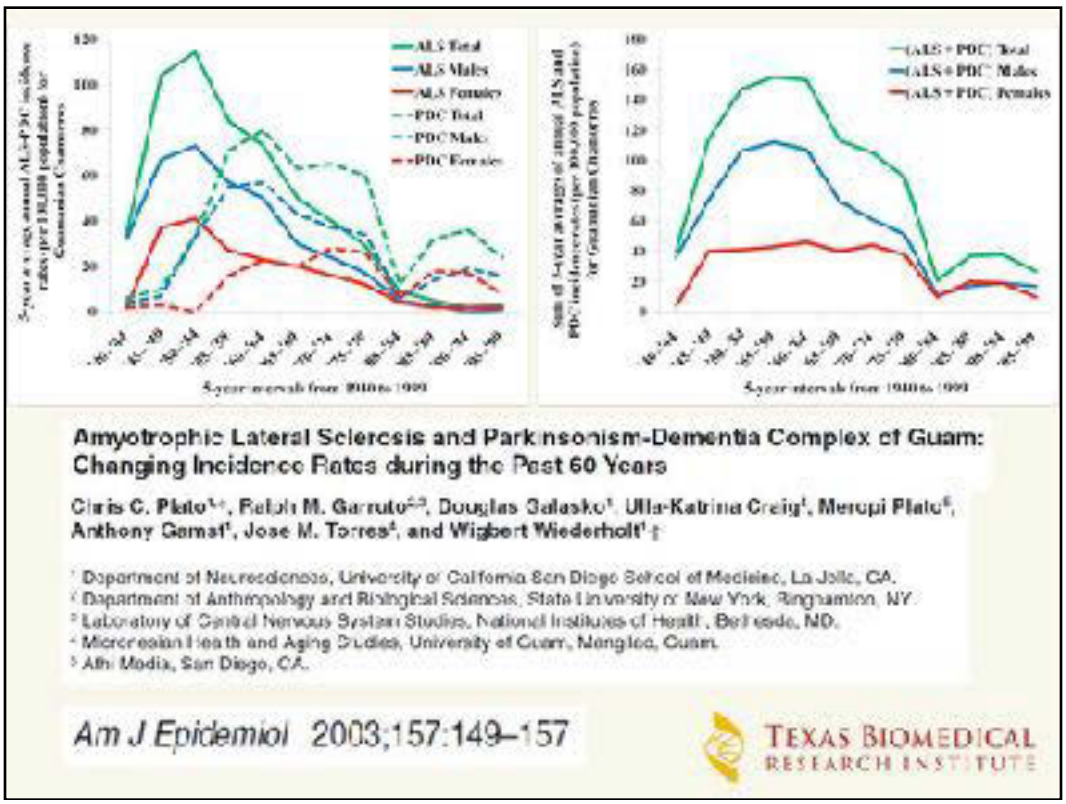

Amyotrophic Lateral Sclerosis and Parkinsonism-Dementia Complex of Guam: Changing Incidence Rates during the Past 60 Years

Chris C. Plato[1,*], Ralph M. Garruto[2,3], Douglas Galasko[1], Ulla-Katrina Craig[1], Merupi Plato[5], Anthony Gamst[1], Jose M. Torres[4], and Wigbert Wiederholt[1,†]

[1] Department of Neurosciences, University of California San Diego School of Medicine, La Jolla, CA.
[2] Department of Anthropology and Biological Sciences, State University of New York, Binghamton, NY.
[3] Laboratory of Central Nervous System Studies, National Institutes of Health, Bethesda, MD.
[4] Micronesian Health and Aging Studies, University of Guam, Mangilao, Guam.
[5] Alki Media, San Diego, CA.

Am J Epidemiol 2003;157:149–157

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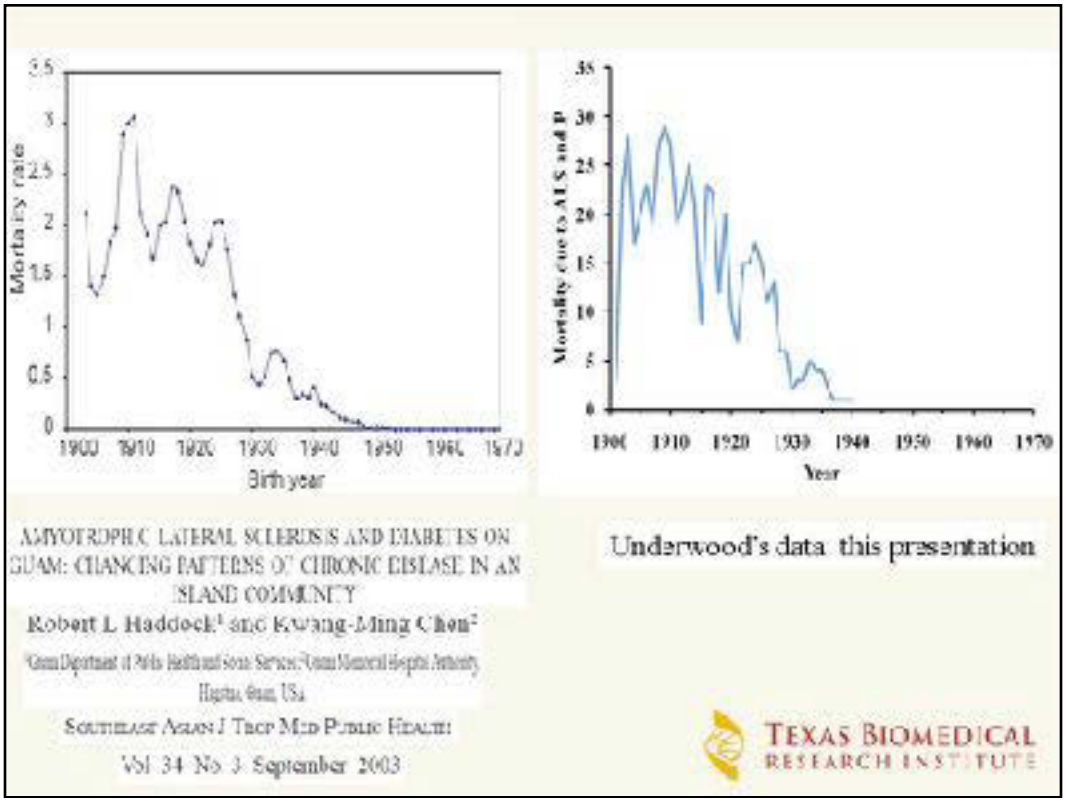

AMYOTROPHIC LATERAL SCLEROSIS AND DIABETES ON GUAM: CHANGING PATTERNS OF CHRONIC DISEASE IN AN ISLAND COMMUNITY

Robert L. Haddock[1] and Kwang-Ming Chen[2]

Guam Department of Public Health and Social Services, Guam Memorial Hospital Authority, Hagatna, Guam, USA

Southeast Asian J Trop Med Public Health
Vol. 34 No. 3 September 2003

Underwood's data this presentation

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Some Results from Analyses of Underwood's Data
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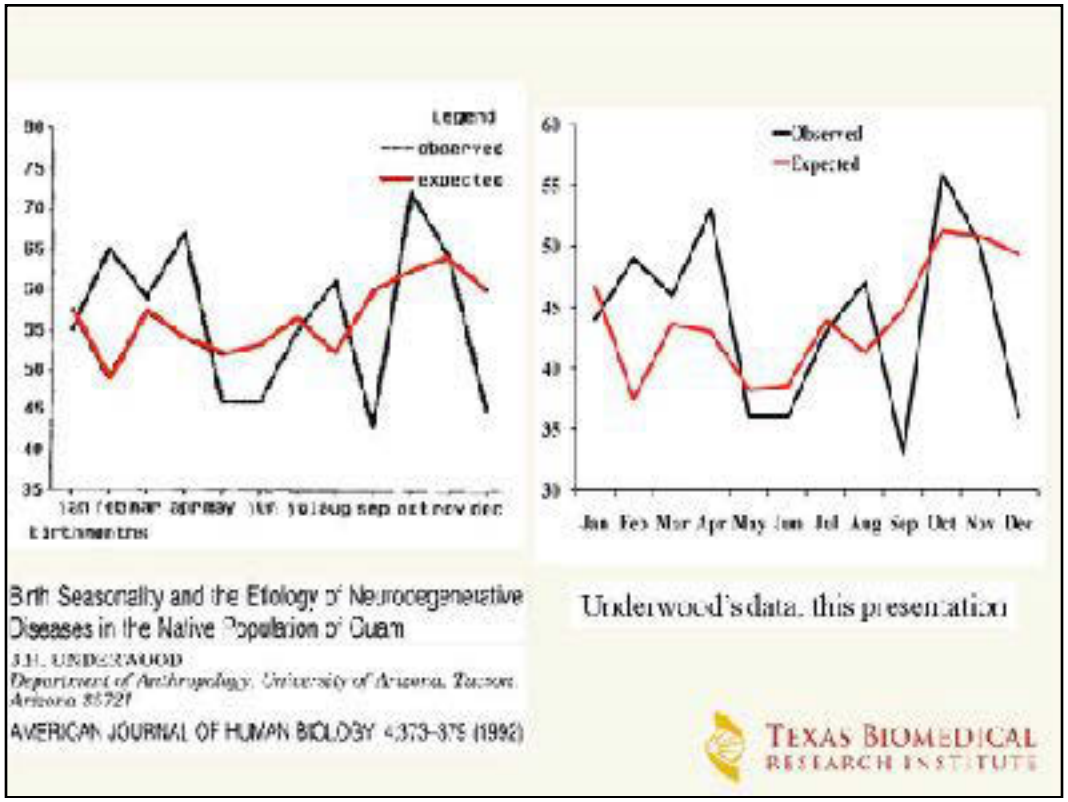
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Birth Seasonality and the Etiology of Neurodegenerative Diseases in the Native Population of Guam
J.H. UNDERWOOD
AMERICAN JOURNAL OF HUMAN BIOLOGY 4:373-375 (1992)
Underwood's data, this presentation
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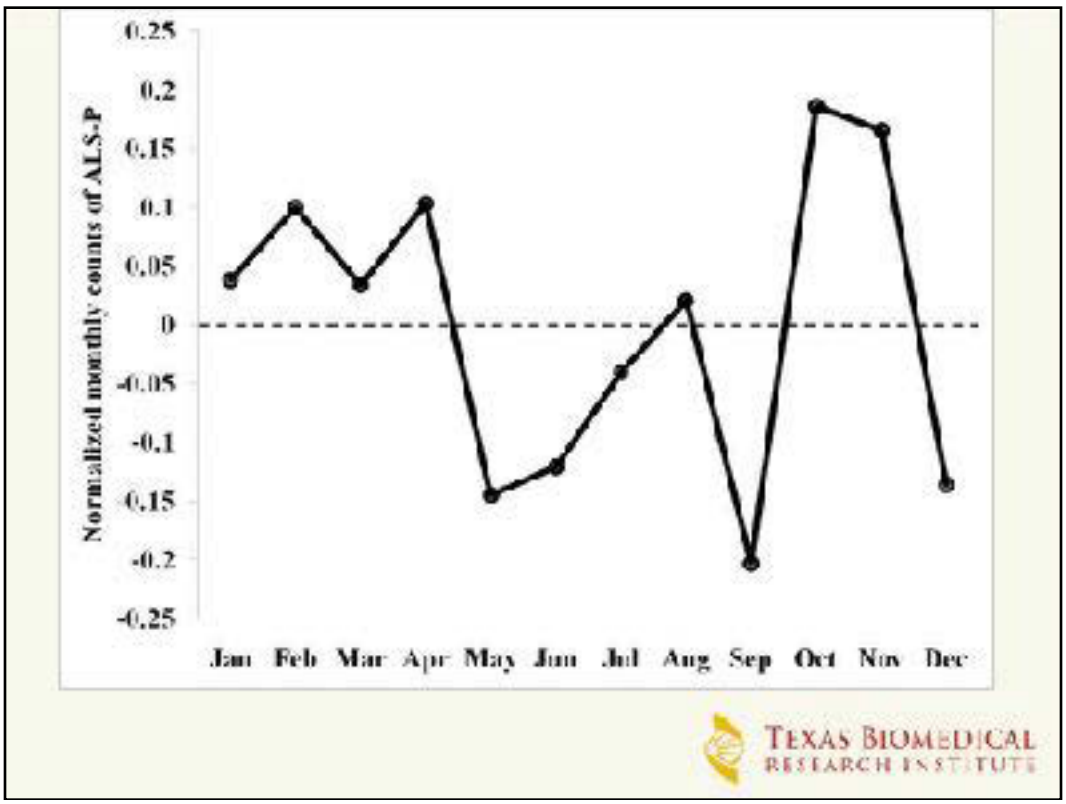
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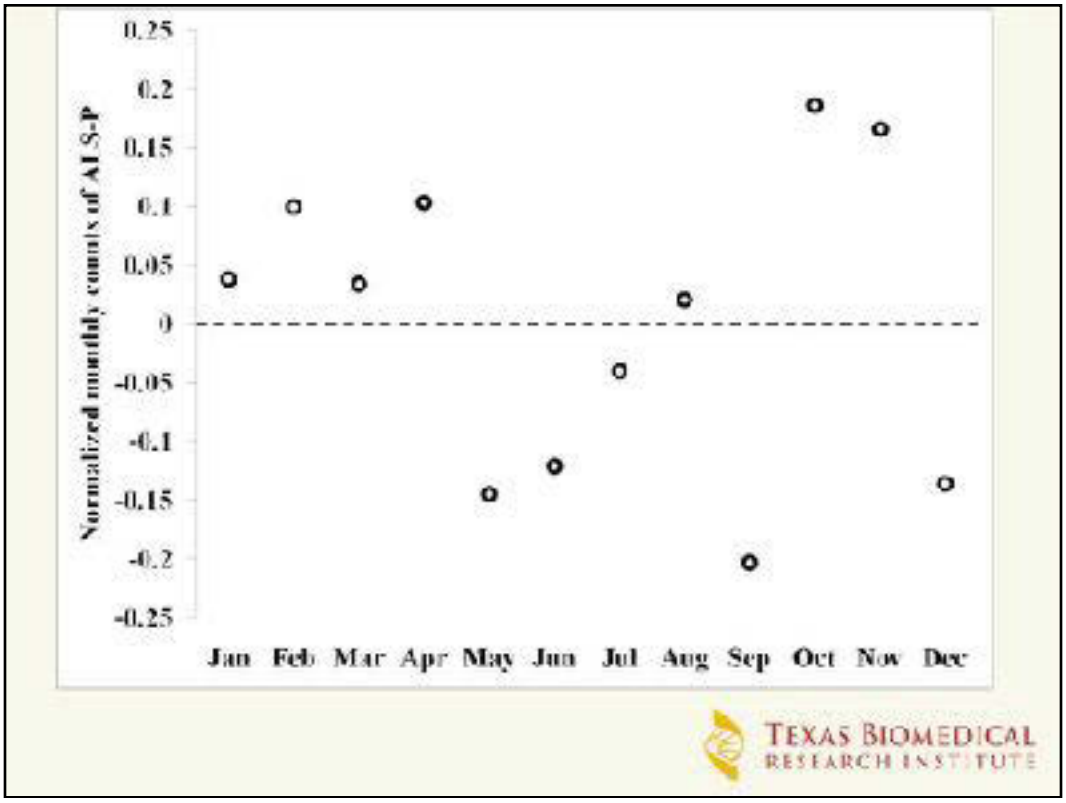
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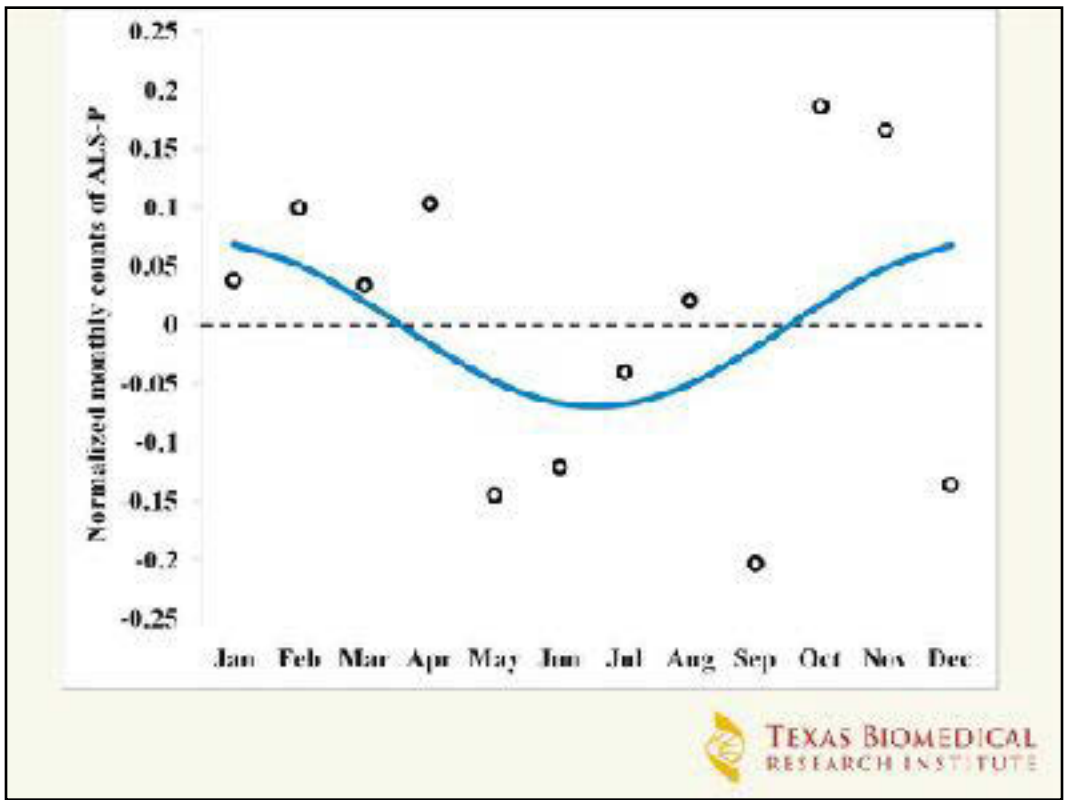
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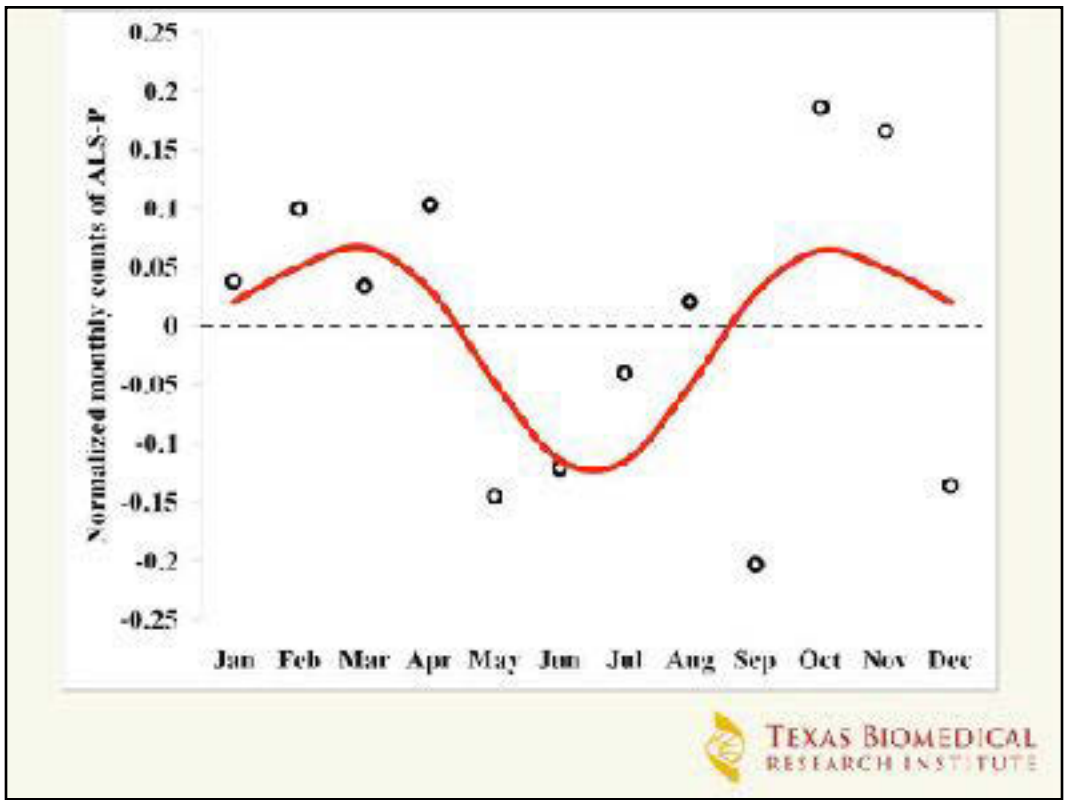
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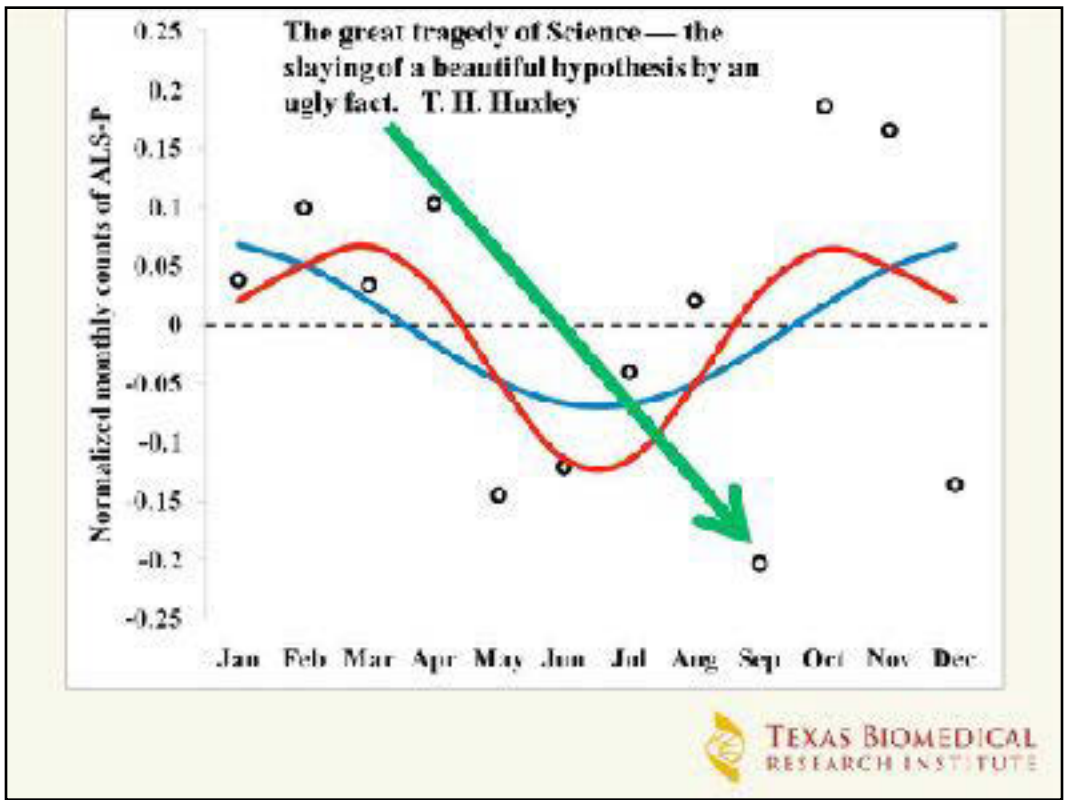
The great tragedy of Science — the slaying of a beautiful hypothesis by an ugly fact. T. H. Huxley
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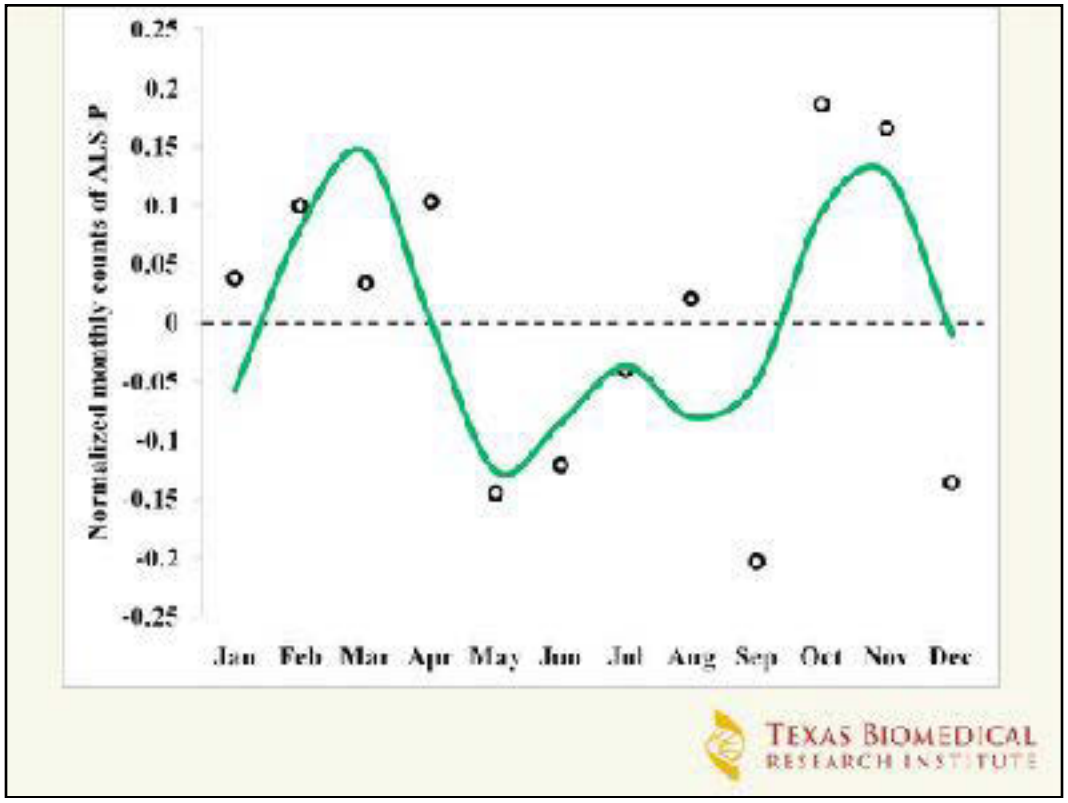
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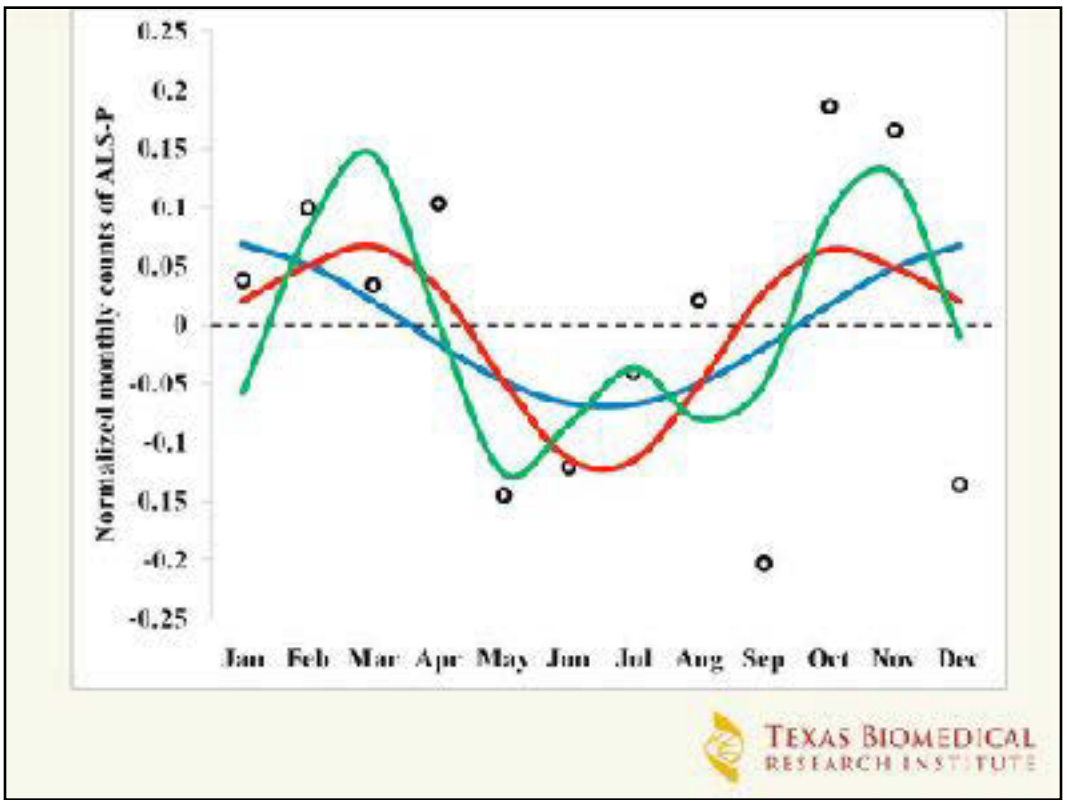
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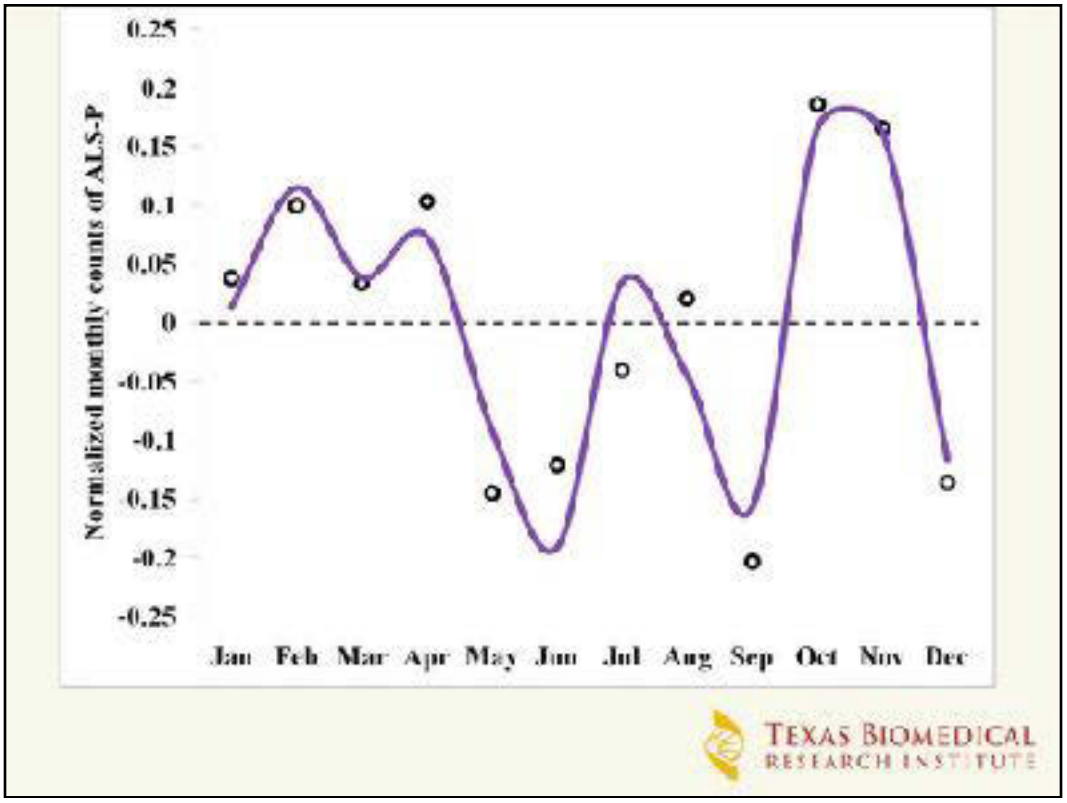
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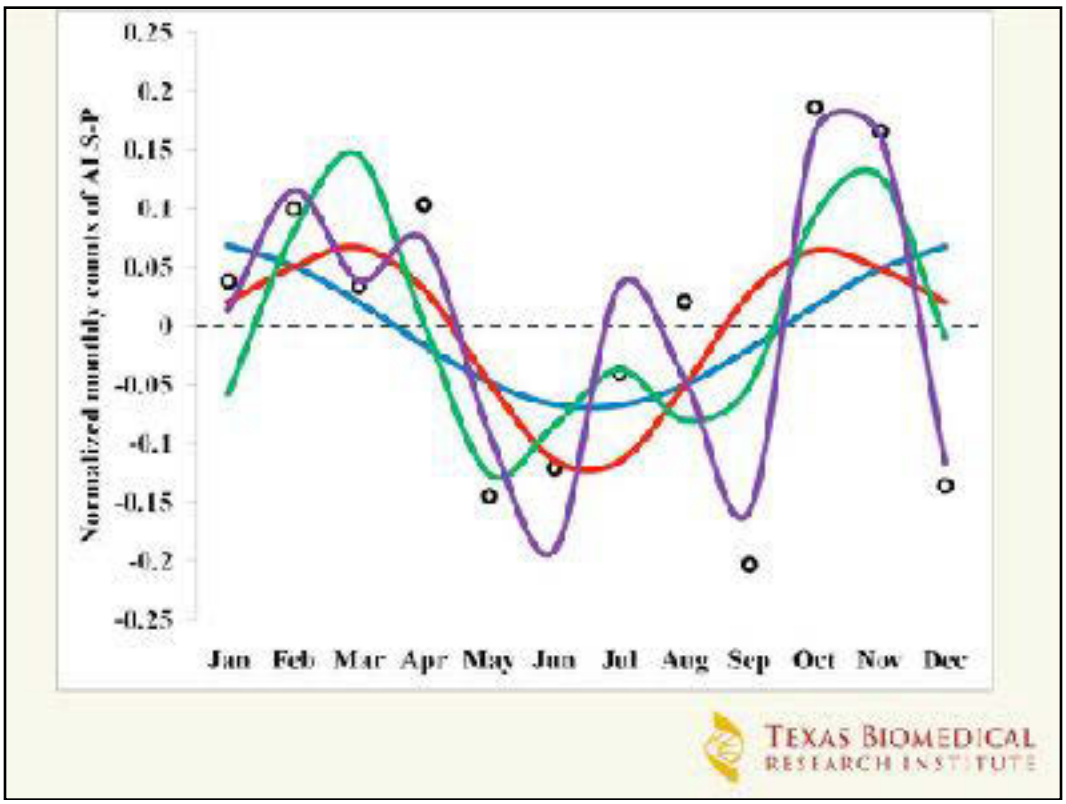
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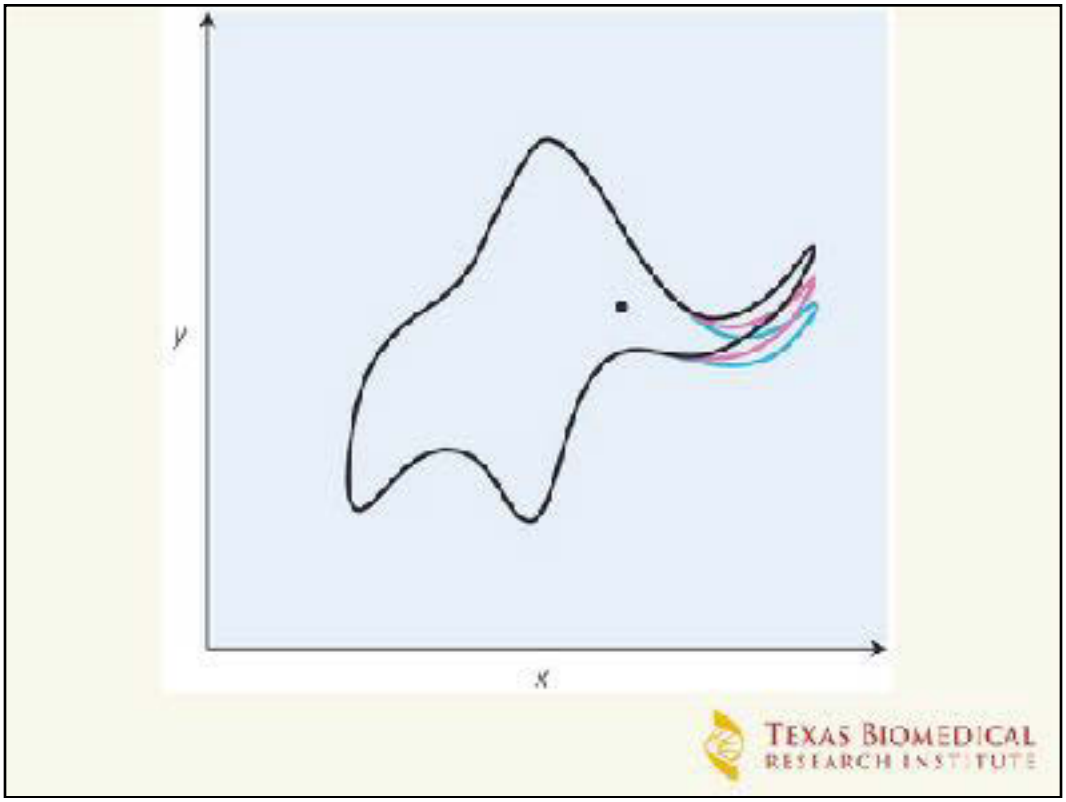
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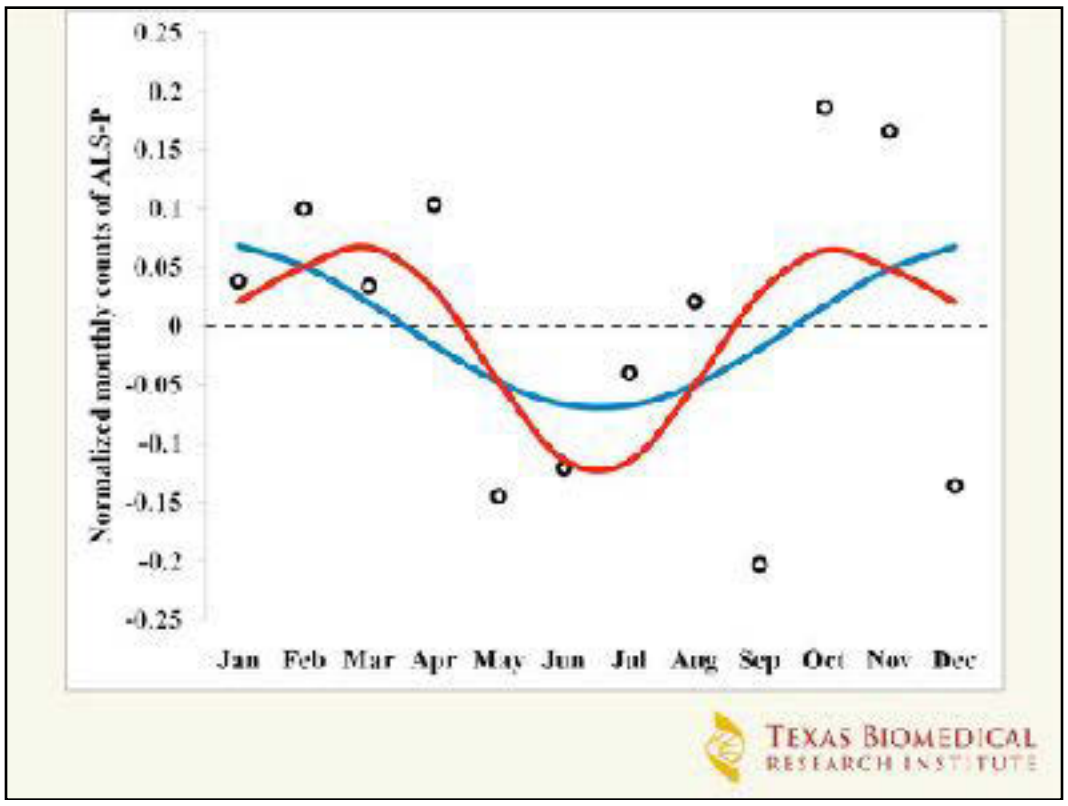
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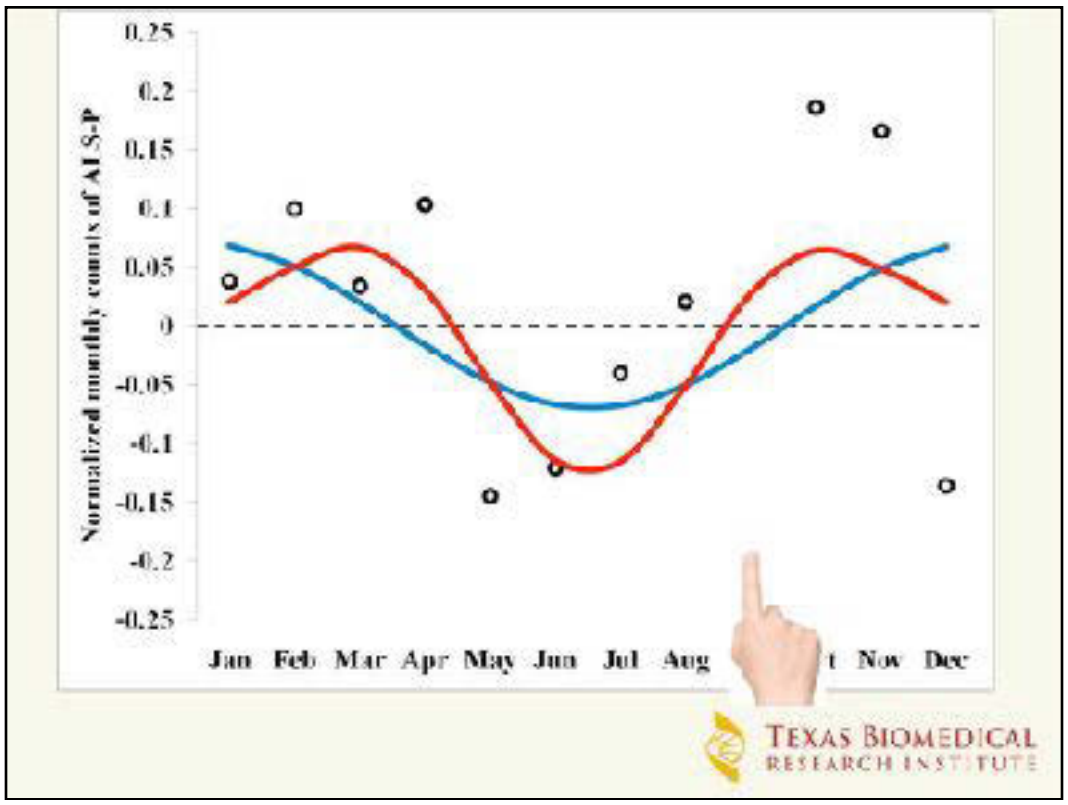
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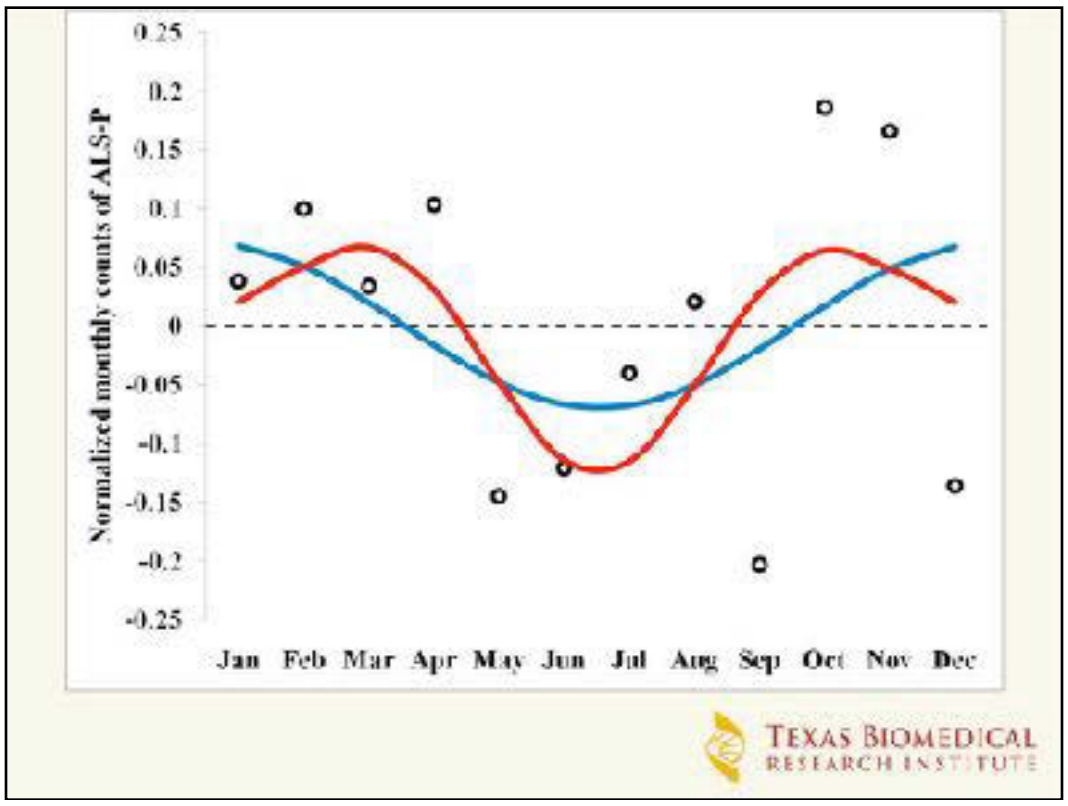
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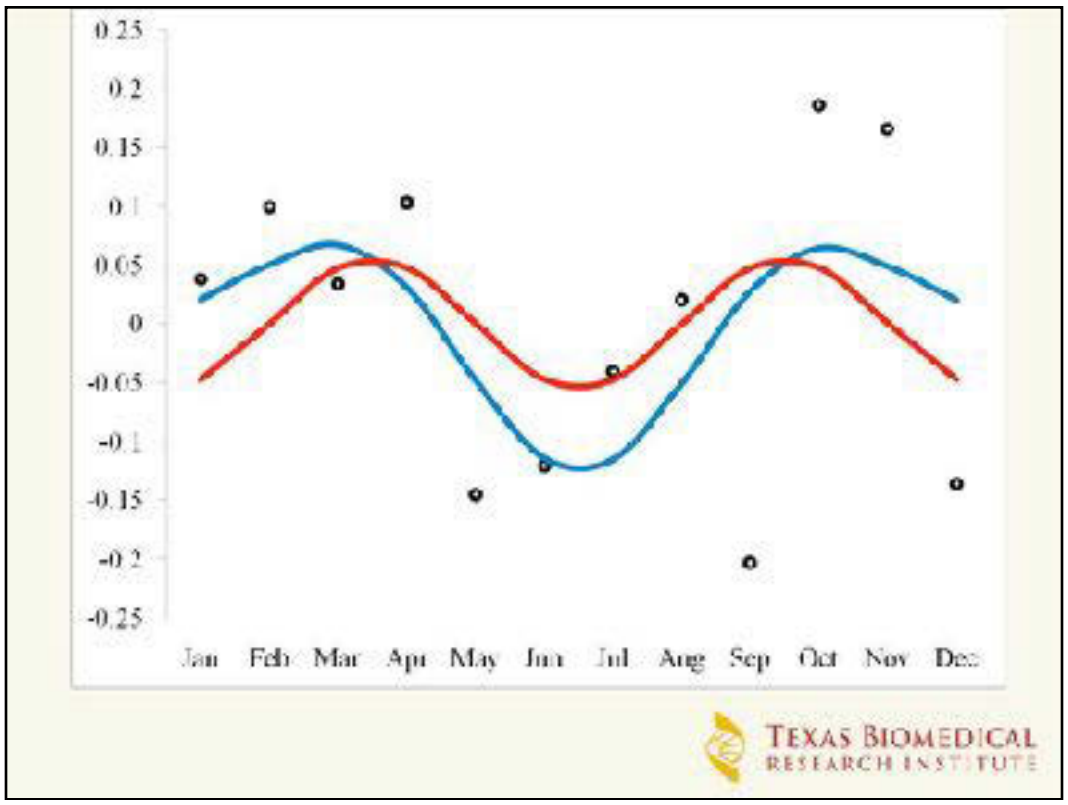
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Underwood's conclusions:

- Seasonality in incidence suggests an infectious disease etiology.
  - First hypothesized by Gibbs and Gajdusek (1972) in J. Clin. Pathol.
  - Much to recommend it.
- In particular, perhaps the mosquito-borne Japanese encephalitis virus was the causative agent of ALS-PDC.

Some criticisms:

- Seasonality is also consistent with the mineral imbalance hypothesis positing aluminum toxicity in the face of calcium/magnesium deficiency. Aluminum is a major constituent of volcanic soils typical in the south and exposure to it is possibly directly proportional to rainfall.
- Seasonality is also consistent with the cyanobacterial toxin hypothesis because cyanobacterial blooms are also seasonal.

Another hypothesis:

- Poliomyelitis, which is caused by the water-borne polio virus, is not only consistent with seasonality incidence but also with several key pieces of historical evidence, unlike the other hypotheses that are consistent with only seasonality (e.g. JEV, mineral imbalance, and cyanobacterial toxins).
- What is called "antecedent poliomyelitis" has been clinically demonstrated to cause ALS, Parkinson's, and possibly dementia.

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Some Supporting Historical Evidence

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I. Primary historical sources recorded an epidemic of poliomyelitis at the earliest possible time for such an infection to be causal given the age-of-onset for ALS-PDC.

- Grunwell, A. G. 1900. Report of an epidemic of acute anterior poliomyelitis of adults on the island of Guam, Ladrone Islands. In: "Report of the Surgeon-General, U.S. Navy," pp. 224-227. Washington: Government Printing Office.
- Leach, P. 1900. Sanitary report on Guam, L. I. In: "Report of the Surgeon-General, U.S. Navy," pp. 208-212. Washington: Government Printing Office.
- Driver, M. G., and Brunal-Perry, O. 1998. Chronicle of the Mariana Islands by Father Ibáñez del Carmen, O.A.R., Father Francisco Resano del Corazón de Jesús, O.A.R., and Others. MARC Educational Series No. 23, University of Guam, pp. 111-114.

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Continued . . .

I. Primary historical sources recorded an epidemic of poliomyelitis at the earliest possible time for such an infection to be causal given the age-of-onset for ALS-PDC.

- On May 9, 1899 the steamer *El Cano* pulled into Apra from Manila with a contingent of about 700 people.
- According to Grunwell and Leach, the subsequent poliomyelitis epidemic started shortly after infected individuals from the *El Cano* came ashore.

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II. The poliomyelitis epidemic affected those areas that would come to exhibit the highest rates of ALS-PDC, the Guam villages of Umatac, Merizo, and Inarajan and the island of Rota.

- From Driver and Brunal-Perry (1998: 112), we have the following excerpt:

> On 13 June of this year, 1899, Father Ildefonso Cavanillas and Father Crisogono Ortín, the priests of Agat and Merizo, came to bid farewell and receive their orders to embark for Manila or directly for Spain via Hong Kong. Once the arrangements for their departure were made, they returned to their *pueblos* **where many were sick** (boldface mine).

- From two different sources, we know that at the time Merizo was composed of Merizo proper and Umatac.

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Continued . . .

II. The poliomyelitis epidemic affected those areas that would come to exhibit the highest rates of ALS-PDC, the Guam villages of Umatac, Merizo, and Inarajan and the island of Rota.

- Safford, W. E. 1905. The Useful Plants of the Island of Guam. Smithsonian Institution, United States National Museum pp. 134, 135, and 137. (see next slide)
- Driver, M. G. (ed.). 2000. The Augustinian Recollect Friars in the Mariana Islands: 1769-1908. MARC Educational Series No. 24, University of Guam, pp. 12-15 (cf. footnotes 31 and 37), and 60. (see slide after the next)

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TABLE I.—*Population according to villages.*

Villages.	Males.	Females.	Total.
Agaña and its dependent villages	3,216	3,616	6,832
Agat (village proper)	397	446	843
Agat (district of Sumai)	331	365	696
Merizo (village proper)	237	279	516
Merizo (district of Umatag)	123	126	249
Inalahan	262	278	540
Total	4,566	5,110	9,676

W. E. Safford. 1905. The Useful Plants of the Island of Guam. Smithsonian Institution, United States National Museum. (p. 137; cf. also his discussion of the roads on pp. 134-135)

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Continued . . .

II. The poliomyelitis epidemic affected those areas that would come to exhibit the highest rates of ALS-PDC, the Guam villages of Umatac, Merizo, and Inarajan and the island of Rota.

- In Driver (2000: 60), there are two noteworthy points:
  - Near the top of the page Fr. Ortin is described as the priest of Merizo and Inarajan.
- For the second point from p. 60, we have the excerpt:

  The Elcano departed the port of Saipan at dawn on the twentieth, stopped a few hours at Tinian, and arrived at Guam at 10:00 p.m., where it entered the harbor and anchored. It remained in port all day on the twentieth; at noon on the twenty-first, **it sailed for the port of Umata to take on water** (boldface mine); . . .

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Continued . . .

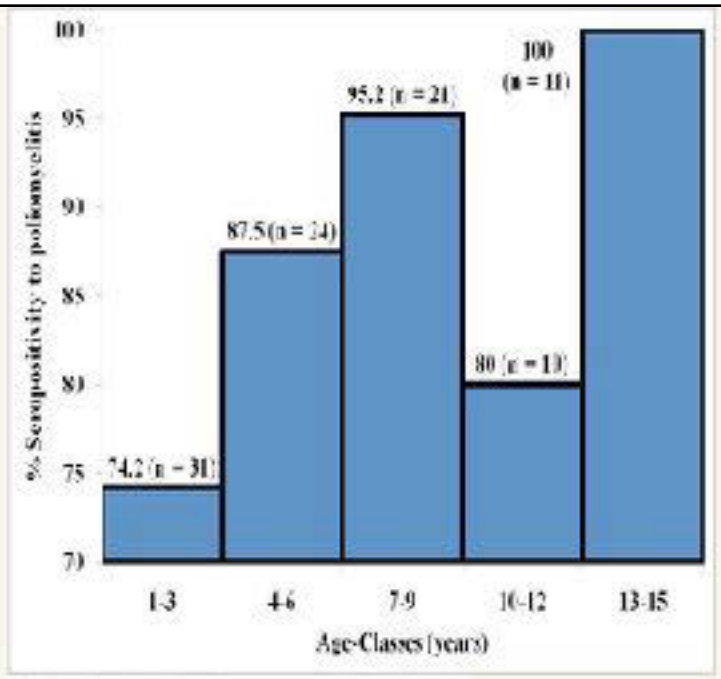
II. The poliomyelitis epidemic affected those areas that would come to exhibit the highest rates of ALS-PDC, the Guam villages of Umatac, Merizo, and Inarajan and the island of Rota.

- Lastly, along these lines that is, we have the following excerpt from Driver and Brunal-Perry (1998: 114):

> On . . . June, Harrison's schooner arrived from Japan. He had come via Saipan and **Rota and brought us the news that the same illness prevailed in the northern Islands** (boldface mine).

III. In the 1940s, it was shown by military medical doctors that polio infection was endemic to Guam, especially in young children, and it was thought that polio infection was endemic ever since the fateful poliomyelitis epidemic of 1899.

- Several papers by W. McD. Hammon and colleagues.
- Hammon, W. McD., Sather, G. E., and Hollinger, N. 1950. Preliminary Report of Epidemiological Studies on Poliomyelitis and Streptococcal Infections: Lensing Neutralizing Antibody and Antistreptolysin "O" Surveys of California Cities, Texas, North Carolina, Mexico, Pacific Islands, and Japan. Am. J. Public Health, 40:293-306.



Results from Hammon et al. (1950)

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Continued . . .

III. In the 1940s, it was shown by military medical doctors that polio infection was endemic to Guam, especially in young children, and it was thought that polio infection was endemic ever since the fateful poliomyelitis epidemic of 1899.

- The following review by Hammon is also critical . . .
- Hammon, W. McD. 1951. Special Reviews: Neurotropic virus diseases. Pediatrics, 8:741-749.
- After relating his findings of prevalent polio infection in young children to the 1899 poliomyelitis epidemic, Hammon essentially argued for a scenario of prevalent inapparent polio virus infection in the Guamanian population in the critical time frame of 1900 up until the time of his work there in 1948.

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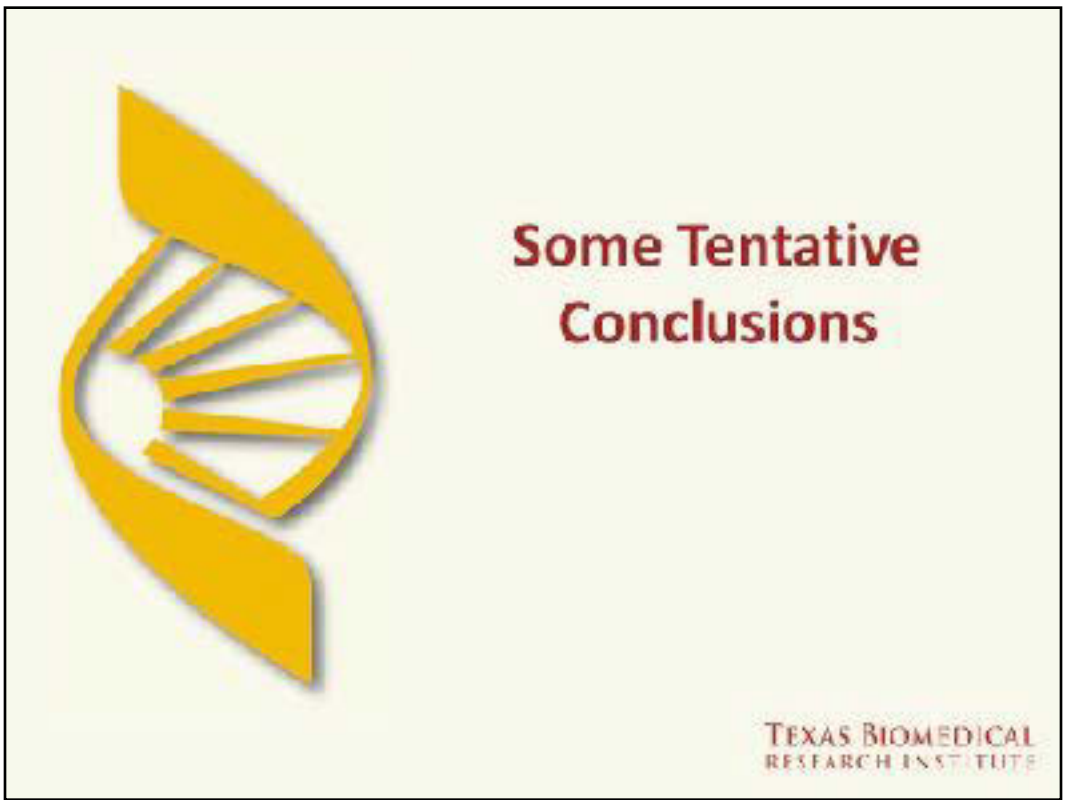
Some Tentative Conclusions
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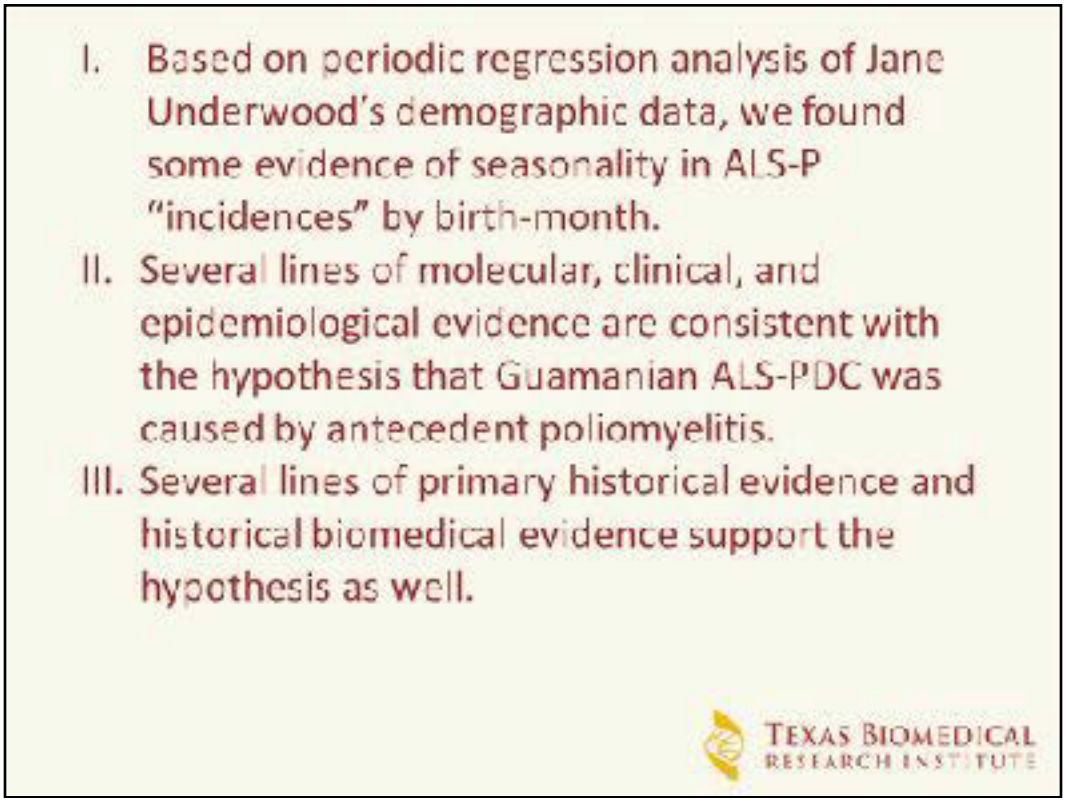
I. Based on periodic regression analysis of Jane Underwood's demographic data, we found some evidence of seasonality in ALS-P "incidences" by birth-month.
II. Several lines of molecular, clinical, and epidemiological evidence are consistent with the hypothesis that Guamanian ALS-PDC was caused by antecedent poliomyelitis.
III. Several lines of primary historical evidence and historical biomedical evidence support the hypothesis as well.
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Some next steps:

- ACTUALLY incorporate sex ratio results.
- Analyze the data using a more advanced technique known as Poisson regression with a seasonality component. I'll be doing this work in collaboration with Dr. Frank Camacho at the Department of Biology here at UOG.
- Perform some stochastic epidemic modeling and simulations to see if the observed patterns can be recovered. I'll be doing this work with Dr. Alex Kerr at the Marine Lab.

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Dangkolu na' si Yu'us Ma'ase!

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Vincent P. Diego earned a bachelor's in biology, and a master's and doctorate in biological anthropology. His master's training was in the mathematical biology of infectious disease, and his doctoral and postdoctoral training were in the statistical genetics of complex disease. Currently, he is a staff scientist in statistical genetics at the Department of Genetics at the Texas Biomedical Research Institute in San Antonio, Texas. His other interests are in mathematical models of infectious and noninfectious diseases, and, the anthropology, defined in the broadest sense, and history of Pacific Island populations, especially of the Chamorro people.

Fall semester 2008, Frank A. Camacho began teaching at his alma mater as the first Chamorro tenure-track faculty member in the Biology Department. Camacho earned his undergraduate and graduate degrees in biology from the University of Guam in 1994 and 1997, respectively. In 2005 he earned his PhD in Biology from the University of Alabama at Birmingham.

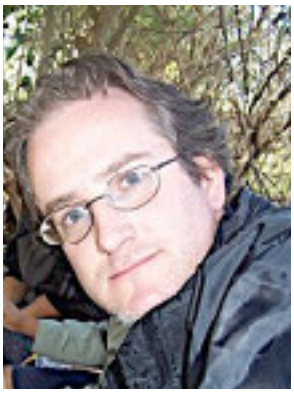
Peopling of the Marianas

An mtDNA Perspective

By Miguel G. Vilar
Scientific Manager, Genographic
National Geographic Society
mvilar@ngs.org

Abstract: *A presentation of research which examined the genetic origins and postsettlement gene flow of Chamorros of the Marianas Islands. The procedure was to infer the origins of the Chamorros by analyzing 360 base pairs of the hypervariable-region 1 (HVS1) of mitochondrial DNA from 105 Chamorros and compared them to lineages from ISEA and neighboring Pacific archipelagoes from the database. As a result, 92% of Chamorros belong to haplogroup E, also found in ISEA but rare in Oceania. The two most numerous E lineages were identical to lineages currently found in Indonesia, while the remaining E lineages differed by only one or two mutations and all were unique to the Marianas.*

Editor's Note: This paper, presented at the Marianas History Conference, was not made available for publication.



Dr. Miguel Vilar is the Science Manager for National Geographic's Genographic Project and visiting faculty at the University of Pennsylvania. Miguel is both a molecular anthropologist and a science writer. His fieldwork has taken him to remote places throughout the South Pacific, East Africa, Mesoamerica, and the Caribbean. In the laboratory he researches the modern genetic diversity of human populations from Melanesia, Micronesia, North and Central America, and the Caribbean. Miguel has published in several anthropology and genetics journals, as well as popular science magazines.