Forest Pathology in the Pacific (FSM, CNMI, Guam and Hawaii), 2015, Trip Report

By Phil Cannon

Figure1. A fresh orange and white mycelial weft of the butt-rotting fungus *Phellinus noxius* advances up the outside of a pengua tree (*Macaranga thompsonii)* near Ritidian, Guam. During Typhoon Dolphin, the bark of roots was cut by the sharp karst limestone as the strong winds rocked the trees. This made it easier for the fungus to become established. The heavy rains that accompanied the intense 2015 typhoon season were also conducive to high levels of mycelial growth and spore production.

Summary

In 2013, the author made his first major trip to investigate *Phellinus noxius* and other forest pathogens in FSM, CNMI and Guam. On that trip, four other forest pathologists joined in for the visits to Guam, Saipan and Pohnpei. Soon thereafter, a trip report and four publications were produced and DNA from isolations made during this trip were sent off for molecular assessment. In the ensuring two years, genetic information gathered from these analyses was generated. Some of these results are presented in the first chapter of this report.

Then, from Oct 25th through Nov. 25th, 2015, the author again traveled to the Federated States of Micronesia (Kosrae, Pohnpei, Chuuk and Yap), the Commonwealth of Northern Marianas Islands (Saipan), Guam and Hawaii (Oahu and the Island of Hawaii) to work on Forest Pathology issues affecting these states and territories. In FSM, CNMI and Guam, the main disease worked on, again, was *Phellinus noxius*, a root and butt rotting fungus that speedily kills a very wide range of tropical tree species. Some surveys were made on each island to search for this fungus and even more intensive future surveys were planned for each island. At most locations where *P. noxius* infection foci were found, samples of fungal fructifications or *P. noxius*-infected wood or bark were collected and isolations were made from these samples onto artificial media. These isolates were subsequently shipped to the Ned Klopfenstein Lab (US Forest Service, Rocky Mountain Station) so the DNA could subsequently be extracted and characterized using appropriate molecular genetic techniques. This information will, after processing, be added to the genetic information gathered for this fungus in 2013. In addition several disease control measures for *Phellinus noxius* were considered and on each island one to three infection foci received some form of corrective treatments on a pilot basis. These Phellinus related activities are also summarized in Chapter 1.

Then, while making the aforementioned observations about *Phellinus noxius* and while attempting the management of this fungus at 18 different sites, it was also noticed that sections of the boles of dead trees that had had previously been colonized by *P. noxius* were, themselves, becoming invaded by an array of different biological organisms that might, possibly, be useful as biological controls for this fungus. This information is summarized in Chapter 2.

Although this work with the Phellinus consumed 90% of the working time on these islands, seven other tasks were also undertaken on this trip; these are reported on in subsequent chapters: In Chapter 3 a report is made of a Colletotrichum-like fungus attacking the leaves of the piper beetle in Yap. This fungus could destroy a multi-million dollar business on that island, so these isolations were made with the purpose of identifying the fungus involved and thereby tapping into the literature on how to manage this disease. In Chapter 4 a report is made on commonly observed invasive vines. Such vines were noticed to be dominating a lot of the landscapes on every island visited. Some potential fungal bio-controls were sought on leaves of the merremia vine (*Merremia peltata*), the most aggressive of these invasive vines.

Chapter 5 explores another problem that prevails in many islands in the Pacific; difficult soils. Palau and Yap, in particular, have a large areas of some of their islands covered with super acidic soils and this condition pretty much precludes decent growth of most planted tree species. Therefore, on Yap, a fertilizer study was established to see if a moderate dose of a multi fertilizer (mainly containing Nitrogen, Phosphorus and Potassium) could alleviate the pH and nutrient problems of young *Acacia auriculiformis* saplings.

As Diane Haase and James B. Friday are currently contemplating putting on a forest nursery course in Chu uk in February of 2016, some scouting was done to see what opportunities await them. Findings on this topic can be seen in Chapter 6.

Similarly, as Kevin Eckert is getting set to deliver a chain saw course in Saipan, some information was gathered, particularly with respect to the storm damage suffered by Saipan's trees. This information is presented in Chapter 7.

Further, on Yap the news was broken that the author would be substituting for David Bakke as the manager of the consolidated State and Private Forestry grant for that country. This grant has been running quite well with David's assistance and the Yapese forestry authorities saw little need to change anything. However, they indicated they would like to do more work in the arena of reforestation on acid soils, management of invasive species, and fire control. They are particularly interested in managing the aforementioned *Phellinus noxius* root rot and *Colletotrichum spp.* leaf spot problems.

On Oahu, the *Acacia koa* research program at Maunawilli was reviewed and a comprehensive koa tour was planned for the visit of Tom Schmidt, Manfred Mielke and Bruce Moltzan who will be traveling out to Oahu and Hawaii with the author in February, 2016. On the Island of Hawaii some additional stops for this koa tour were planned, but the main focus there was to make plans for the Tom Harrington visit (also in February, 2016) when he will come out to look at the *Ceratocystis fimbriata*-caused problem that is killing a massive number of ohia (Metro*sideros polymorpha*) trees on about 35,000 acres on the southeast side of this island.

Very good to absolutely outstanding collaboration was received on every island visited during this tour.

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Chapter 1 *Phellinus noxius* root rot history, distribution and other related activities in Kosrae, Pohnpei, Gaum, Yap and Saipan.

Background Information

Phellinus noxius was first noticed in Singapore by Corner (1932) where it was causing a brown rot of rubber trees. He termed this fungus *Fomes noxius*, but later Cunningham (1965) reclassified this fungus as *Phellinus noxius*. Since then it has been recognized as causing an enormous amount of root and butt rot in many hundreds of tropical tree species and in many countries in the far western Pacific Region (The Commonwealth Mycological Institute, 1968).

The first record of *Phellinus noxius* in the US Affiliated Islands comes from Hodges and Tenorio (1984). During this present trip I had dinner with Jack (Juaquin) Tenorio and he told me that when he found the disease he was the Head of Plant Industry for Saipan and had become alarmed when he saw that a few of Saipan's famous flame trees (*Delonix regia*) were dying. He mentioned this to Mike Robinson, then the State Forester serving for the US Forest Service on Saipan, and Mike in turn contacted Chuck Hodges (an extremely capable tropical forest pathologist then working for the US Forest Service out of Hawaii). Chuck Hodges went to Saipan and their publication was a result of this visit.

After reading their publication, the author, being the Regional Forest pathologist, was curious to see if he could find the infection foci that they had described and so journeyed to Saipan. At that time, Sid Cabrerra, who was also involved in some of this early Phellinus work, generously showed the author not only the original spot of the find but several other locations in Saipan that had *Phellinus noxius*.

Then, in 2010, after co-teaching an arboriculture course in Pohnpei, the author met Gibson Santos, of NRCS, who took him to see a location on his farm which also had a few breadfruit trees with this disease. From accounts from Erick Waguk (Kosrae) and Francis Ruegorong (Yap), who reported trees dying from a "black sock" around their base, it seemed likely that there would be *Phellinus noxius* on these two islands, as well.

In 2013, an intensive three-week effort was undertaken by the author to see if *Phellinus noxius* could be found on most of the major US Affiliated Islands of the Western Pacific. An exceptionally talented team of Forest Pathologists joined in for 8 days of this search. One to eight infection foci were eventually found on each of the islands visited (see Figure2) and isolations were made of the *Phellinus noxius* from most of these infection foci (onto an agar gel) so that the respective DNA could be extracted and genetic sequencing data could be developed for each isolate using Illumina sequencing of double-digest-reduced representation libraries (ddRAD) Stewart et al, 2015.

Several Chapters were written on various *Phellinus noxius* themes in the months following that trip and several of these have been published, since. The relevant chapters in that report from the 2013 trip are as follows:

1) Highlights, personnel contacted and pathology activities undertaken during the September 2013 trip to Yap, Palau, Pohnpei, Kosrae, Guam and Saipan (by Phil Cannon)

2) Classifying butt rot fungi in Yap, Palau, Pohnpei, Kosrae, Guam and Saipan (by Phil Cannon, Ned Klopfenstein, Mee Sook Kim, Yuko Ota, Robert Schlub, Roger Brown, Sarah Ashiglar, Amy Ross Davis and John Hanna)

3) *Phellinus noxius* in the Federated States of Micronesia (by Phil Cannon, Ned Klopfenstein, Francis Ruegorong, Maxon Nithan, Blair Charley, Erick Waguk and Roland Quitugua).

Although that trip ended in Sept of 2013, molecular genetics work continued on the 72 fungal samples that had been collected and isolated from during this trip plus an additional 100 isolates that were provided from other islands (and continents) in the western Pacific area (see Figure2).

Figure2. Locations (red dots) in the western Pacific where *Phellinus noxius* samples have been collected in order to analyze their DNA using genetic markers.

The neighbor-joining tree shown in Figure3 demonstrates the relatedness of the different isolates that, to date, have been examined at the molecular genetics level. It can be seen that the *Phellinus noxius* isolates from Kosrae, Pohnpei, Guam and Palau are all fairly closely related and that these are all related to one of the *P. noxius* isolates that has been found on the Ogasawa Islands of Japan. Ultimately the objective of this study, when all samples have been collected and analyzed, will be to determine how this pathogen has been moving about these Pacific islands. Molecular genetics should also enable determination of how the pathogen has been moving within the territory of each island.

Interestingly, during the 2013 visit to these islands it was assumed that there was very little sexual recombination going on with *P. noxius* based on an almost complete failure to find any sporocarps. Indeed, only six sporocarps were found during that whole trip. However, from this phylogenetic tree (Figure 3) it appears that sexual recombination must be occurring because there appear to be 10 distinct genets of *P. noxius* on Guam and several different genets each on Palau, Kosrae, Pohnpei and Saipan. Unfortunately, this finding also means that the fungus can spread by spores, and even, perhaps, long distances by spores, a fact that will complicate the management of this pathogen.

Although a great deal was learned about *Phellinus noxius* during this 2013 trip, and during the subsequent molecular genetic studies, it was also becoming apparent that we were just beginning to scratch the surface of what we would need to know about the distribution of *Phellinus noxius* in these islands, the impact that this fungus is having on their forests, and possible ways of curtailing the devastation that this fungus can wreak on forests in these Pacific Islands.

Because making studies to address all of these issues (and on so many islands) would cost money that was not anticipated in the regular State and Private Forestry budget it was necessary to apply for some emergency funding. In 2015, a proposal for additional *P. noxius* studies was submitted to the Washington FHP S&PH office for $35,000. This would be enough to send $7,000 to Kosrae (which has *P. noxius* not only in fair abundance in the normal forests and agroforests of that island, but also has it in the the Yela Reserve) and also $3,000 each to Yap, Guam, Pohnpei and Saipan. This money is meant to be used for conducting an "as-extensive-as-possible *Phellinus noxius* survey" of each of these islands and also for initiating at least one *Phellinus noxius* management pilot project on each island.

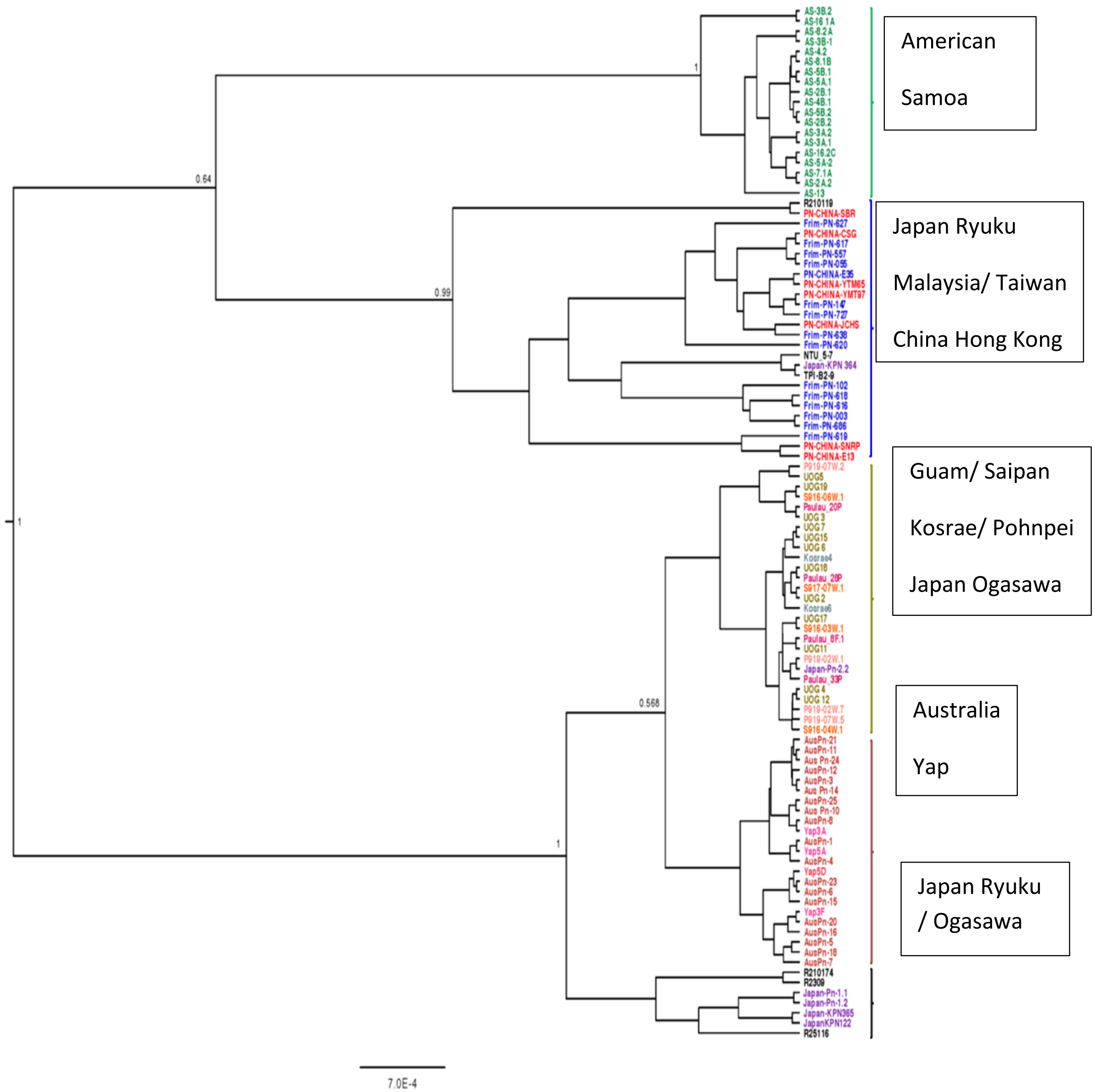

Figure3. Phylogeny of *Phellinus noxius* isolates based on tef-1a sequences (courtesy of Mee Sook Kim). These preliminary results of the ddRAD single nucleotide polymorphism data show multiple genotypes of *P. noxius* that are structured geographically. Isolates from Pacific islands showed reduced levels of genetic diversity, which supports the hypothesis of potential introductions to some Pacific islands. Continued analyses will examine levels of gene flow among populations and determine if population structure by host is present.

The General Approach for Studying *Phellinus noxius* during this Oct. Nov. 2015 trip

During the trip of 2015, the author's main objective was to learn more about *Phellinus noxius* on each of the islands to be visited. Therefore, on all islands, an initial step was to ask a host to convene all stakeholders that should be interested in *Phellinus noxius* to come to one meeting location. At this meeting, a power-point presentation on this fungus was shown and "wanted posters" (Figure4) were handed out. This approach always sufficed to get good *Phellinus noxius* conversations rolling. At this point, many participants would talk about where they had seen Phellinus, and how they thought the fungus had might have been moved from one spot to another. The next step was to get all this information down on a map of that island and the next step was to visit all, or almost all, of the spots that had been mentioned.

Once at a spot (technically referred to as an infection foci), we collected good samples of the fungus and the infected wood; photos were taken of the infected tree(s) and their surroundings and GPS coordinates were written down. Additionally, a few observations on the tree species being affected and the environmental conditions at the site were also made. We were also able to do a little work to determine the extent of the infection foci in each location and also to discuss control measures that might work. In at least one infection foci on each island, and sometimes in as many as three foci, we were also able to install what we considered the most cost and effort-effective control measures. At the end of the visit to each island, a wrap up session was held to describe what had been learned during that visit and also to lay out the next steps for future Phellinus surveys and control work.

Figure4. Ned Klopfenstein and Rodasio Samuel show off a black mycelial crust of *Phellinus noxius* attacking a breadfruit tree during the 2013 visit to Pohnpei. This picture was used for the "WANTED" poster to show island residents what *P. noxius* looks like.

Also, on each island where *Phellinus noxius* was found, both samples of this pathogen and potentially competitive fungi were collected. Then, one evening was spent on each island setting up a make-shift isolation chamber and making isolations from these fungi onto PDA agar in petri plates (Note: on Guam the Robert Schlub Plant Pathology lab was used). The next morning these isolates were sent by express mail to the Ned Klopfenstein lab in Moscow, Idaho, where they underwent a short purification step, conducted by Mee Sook Kim, and were then were sent on to Madison, Wisconsin for an assessment of their molecular genetics. A list of the samples submitted to the Madison lab is shown in Table 2. We are still awaiting results of these analyses. When finished, these data will be combined with other data from *P. noxius* isolations in these islands (Cannon et al 2013; Kim et al 2016) and from DNA information on *P. noxius* isolations from Japan, Taiwan, Indonesia and Australia. Collectively, this information will show us how *Phellinus noxius* has become distributed in this part of the globe.

Salient Results of the Survey and Control Efforts for *Phellinus noxius* during this trip and plans made for future surveys and control efforts for each island visited during the 2015 trip.

Kosrae- *Phellinus noxius*

On Kosrae, *Phellinus noxius* is such a famous phenomenon that it is somewhat affectionately and yet also forebodingly referred to as “Musrash” which, in Kosraean, means “the balding”. As such, asking someone if they have heard of *Phellinus noxius* would only illicit a blank look, whereas the simple question “have you seen “Musrash”?” might evoke a ten minute response about all the places where it has been seen and what trees it has been killing and, perhaps, even, some speculation as to how it got there in the first place. Over the course of two days on Kosrae we went to ten different locations that were known or suspected to have trees infected by *P. noxius.* (Figure 4). We went to **Lelu Island** first, the capital of Kosrae, because the wise older foresters at our initial meeting were pretty sure that *Phellinus noxius* on this island had arrived there because some infected breadfruit root cuttings had been brought there from the Waguk area of the Island They had been a gift to the capital. The first two sites on Lelu Island that we visited did not have *Phellinus noxius*, but the third one, behind a piggery at the **Kenyala Austin farm** most definitely did and furthermore one recently killed breadfruit tree was about to drop on the piggery itself (Figure 4). (Note: *Phellinus noxius* can cause the formation of a lot of hazard trees in urban, rural and recreational settings on Pacific Islands; learning to recognize *Phellinus noxius* root rot should be required in any arboriculture course taught on these Pacific Islands. Once infected by *P. noxius* a tree is likely to die in a matter of a month or so and fall over within a year).

The next site visited was as Tafayat (aka “**Leonard’s cousin’s place”**). We did not have information about how the fungus might have arrived here, but, an entire swath of planted breadfruit trees (maybe 40 trees in total) had been killed by the fungus. The total area affected may have been about 3 acres.

Our next stop was at **Erick Waguk’s** farm, here Erick indicated that a huge patch of breadfruit (50 acres) had been killed earlier as a result of *Phellinus noxius*. This was on steep ground near the back of this farm. The part of the farm that is nearer to the road (3 acres) is being managed for a large number of crops in an amazingly complex and successful agroforestry scheme. Between the back of the farm and the front of the farm there was an 8” dbh breadfruit tree that had had *Phellinus noxius*. Shortly prior to our visit, Eric had piled brush all over the mycelial sheath at the base of this tree, let it dry for a few days, and then set it afire. It appeared that this treatment had been very successful at killing the mycelial sheath, but it was too early to tell if the tree would be able to callus over the fungus affected area and heal it. Also we wondered if the fire scar might now allow some other butt-rotting basidiomycete fungi to colonize the bole of the tree.

Figure5. On Lelu Island, the dead, leaning breadfruit tree in the background had been killed by *Phellinus noxius* and now presents and imminent hazard to the pigs in the shelter, below.

Traveling clockwise around Kosrae, one eventually passes through Utwe and then arrives at **Yesron** and the home of the Uncle of Maxson Nithan. Taking the path that begins just to the left of this home and hiking up a ridge, one first comes to an eight-acre site which was once filled with breadfruit. Two years ago, when Katie Friday and I visited this site with Maxson, most of these trees were already dead but a few dozen were still alive only showing early stages of Musrash. By the time of this present visit, all of these trees had died, too. Fortunately, we were still able to find some breadfruit snags and confirm that the recently dead trees also had been killed by *Phellinus noxius*. Two years ago, also at Yesron, there was another three-acre breadfruit plantation further up the same ridge. Most of those trees were still alive at the time of that visit, although most showed some of the symptoms of Musrash. On this 2015 trip Maxson told me that all of those trees had died, too.

Yela Forest Reserve

One day, seven people went to the Yela Forest Reserve including William William, Blair Charley, Maxson Nithan, Rob, Rickson, the personal relations person for the reserve and the author.

A trip to Yela is always exciting, largely because the only way to get there is by a small boat. This means traveling out into the open sea after leaving the protection of the Okat Harbor, the breakwater and the reef. Out there, there can be some huge swells. Once in the open sea, the boat travels counterclockwise along the coast until there is a break in the reef (caused by the issuance of the Yela River) and this is where you can pilot the boat back in towards land. When the swells are large, the surf breaking onto the reef is phenomenally impressive: beautifully formed, extremely fast, great tubes and giant rooster tails when there is an onshore breeze (as shown in Figure6).

Figure6. The awesome reef break near the entrance to Yela River (Note: we did not arrive in the Yela Reserve on this wave).

On arriving near land you jump overboard into knee deep water and wade towards shore going up the left side of the Yela River. Eventually you arrive at a small shelter and a small bridge that in theory should allow one to cross over the river. During this visit the bridge was not passable (wooden planks had succumbed to termites after just a few months in service), so we waded in through knee deep mud for about 15 minutes. Eventually you arrive at a place where there is more reliable ground and this is also where the forests starts converting to a high proportion of *Terminalia carolinensis* trees (called "ka" trees in Kosraean). These are the largest trees on any of the Pacific islands; some are indeed huge.

Although the ka forest of Yela is phenomenal, there are at least four locations (separated by 100 to 200 meters of healthy ka) where from one to five of these ka trees has been killed by *Phellinus noxius*. Further, the disease seems to be spreading with modest speed (perhaps 3 m per year) from the root system of one tree to the root systems of neighboring trees. There may also be some disease transmission by spores. Indeed, we found one resupinate fruiting body of *P. noxius* that extended 30 feet along on the underside of one fallen Phellinus-infected ka tree; this fruiting body was also about 3 feet wide for most of that length.

It is uncertain how *Phellinus noxius* was first introduced into this ka forest at Yela, but Blair Charlie and William Williams discovered that all of the infected ka trees found so far in this forest seem to be in a straight line. Furthermore this straight line seems to be on terrain that is at a slightly higher elevation (say 6" higher) than much of the other land in this region and this slightly higher piece of terrain also begins at the furthest inland spot on the Yela River to which one can take a boat during high tide and then leads for about one mile to a much higher plateau. It is known that breadfruit used to be raised on this high plateau and that it was brought into town by first bringing it down to this upper Yela River boat landing while traveling through the ka forest. Indeed many of the buttress roots of the giant ka trees had been hacked years ago by machetes (probably to blaze a trail through the forest) and it is precisely at these hacking points where the most advanced *Phellinus noxius* infections are found in this forest. It should be noted that this is an indication that transmissions could be by spores (spores colonizing the machete wounds) or machetes (infective material carried on machete blades).

During the authors visit to Kosrae in 2013, and with the purpose of trying to protect the ka trees that were already had one buttress root infected with *Phellinus noxius,* it was decided to try a popular locally- used remedy for musrash. At that time, the infected fungal sheath was completely removed by using machetes and scraping the buttress root down to the cambial layer. Then, a generous coating of mangrove mud (gathered from the bay) was smeared onto the places where the buttress root had been scraped. This seemed straightforward but we wondered how it would work. During this current visit, two years afterwards, it could be seen that the *Phellinus noxius* had had no problem in continuing to grow up the buttress root that had been scraped and "mudded". This suggests that at least some modification in this control measure would be needed if it was going to be effective.

We also noticed that a few of the Phellinus- infected trees were missing their tops. William Williams remarked that heavy winds had come through the ka forest several months previously. It was very apparent that the trees that were missing their tops were much more vulnerable to *P. noxius*, either because they had way fewer natural defenses or because there were huge courts of infection that were now available for the fungus to colonize.

During this visit, we got the GPS of one *P. noxius* infected ka tree and then mapped every tree within a 50 meter radius of that tree. We then made a determination of whether each of these neighboring trees was infected or not. This constituted the mapping of one infection foci. We also experimented with possible means of protecting the remaining ka trees and clearing up these infection foci. Towards trying to keep the fungus from spreading by spores, the entire resupinate fruiting body of *Phellinus noxius* (measuring 30 feet by 3 feet by ¼") was removed by machete from the underside of the fallen ka tree (see Figure11) and then this fruiting body was composted and covered with mud. Plans were also made to return to this site with a chainsaw with an extra-long bar and then to buck the bole of this infected tree into bolts two feet in length. Subsequently, these bolts should be broken into thumb-sized chips of wood using a Pulaski or pick. This may sound difficult, but it shouldn't be too difficult. When wood decay by Phellinus is advanced, the wood will have lost over half of its dry weight and over 80 % of its strength. (Indeed one can usually poke their hand about 6" straight into a tree bole that has been rotted by *P. noxius)*. Once the bole is chipped, the chips could then be burned or buried. If buried, saprophytic fungi should be encouraged to develop on them and displace the Phellinus.

Figure7. Maxson Nithan studies the *Phellinus noxius* caused decay in a buttress root of a giant ka tree that apparently started when farmers blazed a trail through the Yela Forest. After being cut, the ka tree sent out aerial roots, but these do not seem to be healing the wound significantly.

Figure8. Blair Charley shows the results of the "mycelial-sheath scrape and mangrove mud control measure" two years after applying this treatment. It can be seen that the mycelial sheath resumed growth after this treatment and has been able to extend itself another two feet up the buttress root. Once again, the decayed wood in the hacked-out section on the buttress root, shown at left, suggests that trail blazing may have been a pathway by which *P. noxius* was first introduced into this stand.

For the standing trees that show mycelia sheaths developing at their base or on one of the buttress roots, one of two treatments will be applied. For those trees showing just initial signs of attack, the mangrove mud technique will be applied. Trees showing advanced Phellinus development, should be felled. The infected part of the bole will then be bucked into 2 foot sections and chipped up and disposed of (see ahead). The uninfected parts of the bole can be used to make seagoing canoes or used for other lumber purposes, assuming this is in agreement with Reserve Guidelines.

During our visit to this ka forest, we also found one large ka tree that had fallen over, presumably because it's rotted buttress roots could not keep it upright during the aforementioned storm. The side of this log shows a *P. noxius* mycelial sheath had quickly raced up the about 30 feet along the side of the bole (Figure9). And the underside of this log had been converted to an enormous (10m x 1m) resupinate sporophore (Figure10). We peeled this sheath back and could see that the entire volume of the two lowest logs of this tree had been completely colonized by the Phellinus (Figure11). We therefore peeled back all of the bark and mycelial sheath and put this in a pit and covered it with mud. The next steps will be to buck these two lower logs into two-foot sections and then convert them to chips using a Pulaski or a pick.

Figure9. A *Terminalia carolinensis* (“ka”) tree with some *Phellinus noxius* butt rot had been blown over in a recent wind storm. The Phellinus fungus then raced up the bole to colonize as much volume of this log as possible. Shown here is the mycelial sheath of this fungus; when this photo was taken it had already grown 25 feet from the base of the tree.

Figure10. A small section of the resupinate sporophore found on the underside of the fallen ka tree. This particular sporophore measured 10m x 1m. When active, such sporocarps could liberate billions of spores every day and cause new infections both near and far.

Figure11. In this photo the mycelial sheath and the resupinate conk are being cut away from the fallen tree using a machete. The entire bole, now appearing white, consists of wood decayed to a very advanced state. A close up photo would reveal dark reticulated lines running in a ¾ inch grid system throughout this white decayed wood.

Besides this control work for the known infected trees in the Yela Reserve, plenty of additional survey work also needs to get done. In the ka forest in Yela, it was agreed that the base of every single ka tree in that forest would be carefully investigated to determine if there are any more ka trees that are infected with Phellinus. Additionally every single ka tree, whether healty or sick) will be mapped for its exact position in this forest. This will be a big job as there are 100 acres of ka in this Reserve. Also, each of the known Phellinus infection centers that were visited during this trip will be sampled much more intensively to determine just how big these infection centers are.

It should be noted that there were two more suspected infection centers on Kosrae that were learned about on this trip which were not possible to visit because of time limitations. One of these is near Blair's house. Blair's neighbor, Tolman (who works at the Village Hotel) told me about this spot. Another area is down near Malem according to a property owner there named Noah Dakey. There may be many, many other *Phellinus noxius* infection foci on the island.

A one-two punch approach may be the best way to find all of these other spots. For the first punch, it was suggested that Erick Waguk, Blair Charley and Madison (co-owner of the Village) might be able to mount a campaign to towards locating more of these spots. Erick and Blair can provide the technical information about the fungus, Madison can help out with the Public Relations needs of this program (he used to run the environmental program for Kosrae), and the whole Kosrae forestry service can be involved in distributing the "Wanted Poster" developed for showing how to recognize this fungus and giving contact numbers so the disease can be reported. Very fortunately Robert Jackson and Roger Brown (at the University of Guam) have had been communicating excellently and the grant for the Phellinus funding has been set up.

Once a much more complete idea is obtained about how *Phellinus noxius* is currently distributed in Kosrae, and how it is being distributed about the island, and the extent of its impact, the appropriate control measures for Kosrae can be discussed. It is expected that these may be very different for different property owners. Perhaps finding some additional funding for Phellinus activities will be important in 2016 and 2017.

Figure12. In the ka forest of the Yela Forest Conservation area, one giant ka tree has been killed by *Phellinus noxius* and fallen to the ground leaving a big hole in the canopy. A great deal of additional sunlight is now able to penetrate to the forest floor.

Some people may question why it is so important to manage *Phellinus noxius* (limit its impact). There are many reasons. One, of many reasons, is illustrated nicely in Figures 12 and 13.

Figure13. Within months after the ka tree referenced in Figure 12 had fallen, there were already exotic invasive weeds moving in quickly to colonize the newly available space. When these invasive species become established, they can completely preclude the regeneration of native forest trees in this space.

Pohnpei-

On a Sunday, Sept. 1st, the author spent the day traveling mostly through the Kingdom of Madolenihmw and saw many marvels, including Nan Medal, but no *Phellinus noxius*.

Figure14. A peaceful moment at Nan Medal. Some of the palm trees had Ganoderma on them but no *Phellinus noxius* was encountered this day.

On Monday, Gibson Santos, of NRCS, had arranged a high level meeting with Doria Rossen (US Ambassador to FSM), and Bill Cook (Economist with the US Embassy), so the visit to Pohnpei started out quite propitiously.

Subsequently, Gibson had convened an Island-wide meeting of all persons interested in *Phellinus noxius*. This was held in the NRCS building. About 30 persons participated.

We began by running through the wanted poster (Figure4) and then a power point presentation on *P. noxius* was provided by the author. Subsequently, we put a map of Pohnpei on a wall so that people could put up sticky notes showing eight places where they thought they had seen the fungus. Then 12 of us set out to visit most of these sites. What we found at each of these sites will be provided in continuation.

Near the Black Sand High School baseball park; breadfruit trees were dying, but although the bark was black and scabbrose on these trees, this was different from the mycelial sheath of *Phellinus noxius* and inside the trees there was no decay. Something else had killed these trees.

Next we visited was the Kingdom of U. To get there we went by the site of the old Village hotel and then drove up a valley and then eventually up a ridge until we were about 1000 feet above sea level. There we stopped in a small hamlet. The occupants quite friendly but were very busy trying to get some big loads of sakau ready for transport down to Kolonia. They pointed us to a nearby hill top where there were two dozen breadfruit trees were dying. We went to inspect these trees. From their state of decomposition, it looked like they had all died at almost exactly the same time, about seven months earlier. Furthermore, when we looked at the base of these trees we could see that the bottom foot or two of these dead trees was almost invariably darker in color than upper regions of the same tree, but again there was no evidence (neither sign nor symptoms) of *Phellinus noxius* being involved. It was concluded that something else had caused the death of these trees and indeed, after this conclusion had been reached, one of the participants said that this area had been hit by a minor typhoon (locally called a banana typhoon) exactly seven months earlier. Also, on closer inspection (made possible by hacking with a machete) it was possible to determine that the darker color seen at the base of these dead trees was attributed to rain water flowing down the main stem and accumulating at the base of these boles.

The next two days of this trip were spent in the Kingdoms of Netti and Sokehs, respectively, and, and in both of these kingdoms, we found a considerable amount of *Phellinus noxius*. Near the home of Gibson Santos (in Netti) we visited four sites. At Gibson's house we begin by going first to the large breadfruit tree that we had first seen during the 2013 visit. At that time it just had two early mycelial sheaths developing on each side of the tree (Figure15). Since then, however, this tree has been much more thoroughly colonized by *P. noxius*, has died, has fallen over and has become thoroughly consumed by *P. noxius*. Very curiously, however, the succession of events did not stop there. Now there are also a few sections of this log, which had once been completely occupied by *P. noxius*, that have been taken over by Ganoderma (another root-rotter but typically a little less aggressive than *P. noxius*) and some saprophytic fungi.

Figure15.In this 2013 photo, Gibson Santos points out the advancing sheath of *Phellinus noxius* on a large breadfruit tree in his back yard. His uncle, Joab, holds shampoo ginger, thought to be an effective deterrent of Phellinus.

Nearby this tree we checked out a much younger breadfruit tree had also had an incipient attack at the time of the 2013 visit. At that time the mycelial sheath at the base of this tree was scraped off using a machete and then, this scraped part, was pounded with the gel of the shampoo ginger. At the time of this 2015 visit, the shampoo ginger appears to have worked to kill the *P. noxius*, as evidenced by the disappearance of the mycelial sheath. Unfortunately, the act of creating a large wound near the base of the tree (by both the Phellinus attack and then the scraping) has allowed other butt rotting fungi to become established in this tree and rot it out to the point where the strength of the interior of the tree was no longer sufficient to keep the tree upright.

The next site we visited is on land of Gibson's Uncle, Joab Santos. At this location at least a dozen trees had been killed by *Phellinus noxius*. In this infection foci, there was one big stump (five feet tall and 1.5 feet in diameter) that had two big purple conks (Figure16) on it and one small purple conk. All of these conks were found in the inside of a hollow part in the trunk and were seen only after we tore the stump apart using a pick. One of the control measures that we employed was to remove and bury the conks (except for one conk which was collected for DNA purposes) and completely shred the stump to thumb-sized bits (this included as much of the root system as we could pry from the ground).

Figure16 Joab Santos hold a *Phellinus noxius* conk to show the bottom (at left) and top of that conk. This conk was found deep down inside a very rotten stump.

Near this stump, in all directions there was evidence that many additional trees had become infected with *P. noxius* (Figure17). We made a quick map showing all the trees near this stump that were infected, calling this area the infection foci. Then we scratched a line in the soil where we thought the fungus had extended to and then went out another 15 feet beyond that line and scratched a second line. Where this second line was scratched we dug a trench down to one foot of depth (Figure18) and then placed a slurry of composted pig manure. When finished, this slurry that was about a 2" deep and 4" wide. The slurry was then covered up with soil. The purpose of the pig manure was to stimulate growth of saprophytic organisms so that these, in turn, will be able to deter growth of *P. noxius*.

Figure17. Joab finding that many of the trees near the big rotten stump have also become infected with *P. noxius.* On the right a very characteristic mycelial sheath can be seen growing up the base of this young breadfruit.

Figure18. Marlyther Silbanuz shows excellent form (and spirit) digging the trench for the composted pig manure which was applied in an effort to deter advancement of *P. noxius.*

Then we went up the road that goes up the ridge from Joab's farm and eventually arrives at the **"Seven Waterfalls natural wonder".** Along the way, we stopped at Jeremiah's farm (elevation of about 400 feet) and saw that here that a few trees right near his house had been killed by *Phellinus noxius*. Some small resupinate fructifications were found at the base of one of these trees. Nearby there were a handful of small breadfruit sprouts also showing the tell-tale mycelial sheaths of *P. noxius*.

Even further up (specifically near the last house before the waterfalls) we found some more breadfruit trees that had been colonized by *P. noxius*. This was at 700 feet in elevation. We were told that there were many more infected trees even further up, but the road turned to a path at this point so we stopped. Additional survey work up this path sure seems like it would be worth the effort.

The next day, in Sokehs, we went to the village near the base of **Chicken Poo Mountain**. There we saw that the breadfruit that had been alive during our visit two years ago (but which had a mycelial sheath at that time) had since died, become completely colonized by *Phellinus noxius* and had fallen over. This 18" diameter log now had a 2' by 6' resupinate sporophore on the underside of the fallen log, and from a section of this sporophore a pale purple haze of spores was issuing forth (Figure 19). This purple haze was very obvious and in about one cubic foot of atmosphere, you could see hundreds of thousands of individual spores drifting about in Brownian motion. We did not actually do anything with this tree, but, as this was Rodasio's village we did suggest to Rodasio that he and his fellow villagers consider bucking the log into two foot lengths and also extracting as much of the root system as possible. Then we suggested chipping all of these two-foot bolts and the roots into thumb sized bits and burning or burying all of this biomass.

Figure19. A purple haze of spores was seen issuing forth from a fructification on the underside of this log. In this picture there is now a dusky-looking accumulation of spores lying on the ground below this fructification. Billions of additional spores have also left this fructification, but as they have a very low density, they have simply drifted away on air currents, perhaps for miles. Some of these spores may land on a wounded but as-yet-uninfected tree. If the conditions are right (the wound is fresh, and the humidity of the air is high) then they will be able to colonize this tree and start a new infection foci.

Unfortunately this measure may be already be too late for keeping another large (3 foot dbh) breadfruit tree in a different part of this village from becoming infected. Behind one of the houses, it was noticed that one of the trees, that had been perfectly healthy (or at least entirely green) during our 2013 visit, had now lost all of its foliage and died. We checked this tree out and confirmed that it, too, had died as a result of *Phellinus noxious*. It was difficult to be certain how this tree has become infected. However, ten feet from the base of this tree we found a large waste pit that had been dug by the villagers and filled with a variety of refuse. It is possible that some of that refuse might have contained sections of the previously described tree that still had live inoculum present. We agreed that this second tree should also be felled, bucked into short sections and then chipped up to destroy the inoculum.

During the previous visit in 2013, some of the people that were most interested in *Phellinus noxius* were a group of coffee growers that were in the process of establishing 9 acres of coffee on a hillside above Palikar. During that visit we had noticed that one tree (that was still alive at that time) was showing a *P. noxius* mycelial sheath near its base. During this 2015 visit we returned to this site, found the affected tree (which was now dead) and checked on all neighboring trees which fortunately were still alive and showed no sign or symptoms of *P. noxius*. Then, with the expectation that we could limit the spread of *P. noxius* from this infection foci, we did two things: 1) we dug a one foot deep trench around the dead tree that was approximately 30 foot distance from that tree, and then we filled this trench to a depth of about 1.5" with urea fertilizer (using 47 lbs of this fertilizer in the process). We then covered this trench up with soil. As a final measure, we also inserted about 3 pounds of urea into a series of cavities made into the base of the dead breadfruit and the major root system buttresses. These cavities were made with a pick and then 4 ounces of urea was inserted into each of these cavities. Each "treated" cavity was sealed into place with wet soil. It is hoped that the urea in the trench will promote other micro-organisms (like *Tricoderma viride*) that will act as a barrier to *P. noxius* spreading underground. It is further hoped that the urea placed in the dead stump will also promote the development of saprophytic fungi that can displace the *P. noxius* that had already colonized the bole of this tree and thereby significantly reduce the number of spores that might have been produced if this tree had simply been allowed to decay to the point where it was producing sporophores.

We closed out this particular *Phellinus noxius* session in Pohnpei with a debriefing. We went over everything that we had seen during the trip and most importantly we agreed in future assignments.

Going forward, Gibson will be in charge of handling the *Phellinus noxius* survey in Kitti, Rodasio will be in charge of the area around Chicken Poo Mountain; Mt. John Winchep and Klastine will be in charge of N. Sokehs; Marlyther will be in charge of the Kingdom of Madolenihmw and Bejay Obisbo will be in charge of the Kingdom of U.

Chu uck

Only two days were available on this trip to explore all aspects of forestry on Chu uk. A search for Phellinus was done which involved quickly scanning about 3,000 trees for sign or symptoms of *Phellinus noxius*. No evidence was found. As it would have been impossible to show live examples of Phellinus on this island, the sign and symptoms of this fungus were carefully reviewed with Kantitos Kanas, Basiente and Julian largely by showing the "Wanted" poster and talking about the characteristics of this fungus. It is hoped that these three foresters will be able to check on many more trees in the upcoming months. However, of these three top Chuukese foresters, Kantitos is the only one currently receiving a salary, and his responsibilities are largely administrative.

Figure20. The nursery in Chu uck had fairly good infrastructure but was inactive at the time of this visit.

Figure21. Trees had fallen on a high percentage of houses in Chu uck (maybe 50%) as a result of the high winds experienced during the most recent typhoon.

Figure22. Very large proportions of the Chu uk landscape are now covered in invasive vines (80% of Weno Island and 20% of Tenowas Island). Merremia was the most common vine seen and these vines were often 5 to 20 feet deep. It was very difficult to look for *P. noxius* at the base of any trees that had been buried beneath these vines.

Guam

In preparation of the arrival of the research team in September 2013, Bob Schlub had conducted a two-day search of Guam's urban landscape for *Phellinus noxius.* He found no evidence to suggest that the fungus was there, in spite of the fact that he had seen *Phellinus noxius* in a homeowner's yard in Guam in the mid 90's. During the 2013 visit itself, the pathology team also ran a pretty intense search for *P. noxius* and also failed to turn up any evidence. We were beginning to wonder if *P. noxius* had any influence on the health of Guamanian forests.

Fortunately, during that 2013 we also gave a thorough power point presentation on *Phellinus noxius* to 26 interested people in a University of Guam lecture hall, and, in the ensuing months a couple of these parties (the Forest Service Forest Inventory Analysis Group (under the direction of Ashley Lehman) and the University of Guam (Roland Quitigua) found the fungus in a couple of locations. Furthermore, since these finds, the fungus has been found in several more locations by Jim McConnell's team (GPEPP: Guam Plant Extinction Prevention Program) while they were doing a broad survey of forest vegetation on the island.

Figure23. Location of major *Phellinus noxius* finds in Guam made by GPEPP.

Figure24. Mario Martinez stands in a small *P. noxius* infection foci.

Figure25. The heights that the *P. noxius* mycelial sheath can extend up the tree can vary greatly; almost 8 feet for the tree on the left and only 8" for the tree on the right.

Figure26. This tree had been killed by *P. noxius*. No fruiting structures were obvious when the tree was upright, but when the stump was pushed over and upended (as shown here) a massive rusipinate fruiting body (which appear dark and crusty in this photo) was found to be covering the underside of most of the main roots.

During this 2015 trip we were able to visit a few of the areas found by these groups. The first spot we visited was the North Field of the Anderson Air Force Base (Figure 23). This infection foci was first noticed during the installation of an *in situ* species conservation area to protect the last mature *Serriathes nelsonii* tree on the Island of Guam. Just outside of a fence (which had been set up to keep people, deer and wild pigs out of this Conservation Area) there are a huge number of trees that are infected with the fungus. These trees are first noticed because they are recently dead, but on further inspection one could see that most of these dead trees had a black mycelial crust (a key sign of *Phellinus noxius*) lining the underside of their root system (Figure 26). It was also possible to see the direction that the disease is advancing through the forest because the first roots to show this black stalking on a newly infected tree are the ones that are closest to the center of the infection foci.

Very curiously it appears that most of these trees seem to have been killed at about the same time, specifically from about seven months prior to the timing of this visit. On closer inspection, it appeared that there was some wounding and some callus growth near the base of many of these trees; pigs and deer could have been involved, and indeed we found deer poop right near some affected roots. It is also likely that high winds have had a deleterious effect. Particularly where tree were growing on karst limestone such and when they as so exposed as on top of the Ritidian Ridge. When these trees were rocked back and forth by strong winds, this sharp rock could have sliced through the cambial tissue of the tree roots. It should be noted that the eye of Typhoon Dolphin came exactly through this Ritidian Ridge area on May 15th 2015. Wind speeds recorded at Anderson AFB were 106 mph during this storm.

http://www.weather.com/storms/typhoon/news/typhoon-dolphin-threatens-guam

In sum, it is likely that the combination of sharp rock and high wind speed was especially damaging during this period.

There were also a few other things could have happened during this storm which would have favored the development of the fungus:

The far wetter than usual weather could have favored the development of basidiocarps and with them the formation of countless billions of spores. And, indeed, one or more sections of resupinate fruiting bodies were found on the bottom side of the root systems of most of the Phellinus-killed trees (Figure 26). Further as the wet weather continued, this would have favored the colonization of these spores where these may have landed on tree tissues exposed because of limb and bole breakages or root abrasions (these all could have occurred frequently during such a heavy storm). This weather would also have favored the development of the *P. noxius* mycelial sheath as there seems to be a very close link to the places where the mycelial sheath forms and the locations where free water tends to accumulate at the base of a tree during heavy rain events. It is also likely that extended rainy periods would promote the fungal colonization of sapwood and heartwood tissues in recently dead hardwoods as the moisture content in dead wood often soars during periods of heavy rain. The water content in wood near the base of a standing dead tree dead tree would be especially likely to accumulate water due to stem-flow down the bole during storms and thereby promote especially aggressive colonization by the fungus. All of these possibilities, collectively, might explain why the juncture between roots and boles of so many of the dead trees found on Guam were so highly and equally colonized by *Phellinus noxius*.

One of the questions that we addressed while we were at this site was "what could be done to alleviate the *Phellinus noxius* problem". While considering this question we pushed around a few dozen Phellinus-infected trees and, somewhat to our surprise, we found that we could very easily extract almost any of these trees with very little physical effort. The trees could be pushed over easily because their root systems were completely rotted and offered little resistance. As a result of this, we could easily extract the entire root system in the area of the bole of the tree and this was including the mycelial sheaths and the resupinate fructifications on the underside of these roots. Furthermore, we found that by using a pick, and with very little additional effort, we could even remove the radiating root system of infected trees with some ease down to a point where these roots were about 1/2" in diameter or less. Thus, it should be possible, with little effort, to remove 95% of the inoculum from the site.

Therefore, if the boles and the root systems of all infected tree in an infection foci could be removed down to the point where the roots were less than ½ in in diameter, and then all of this material was chipped up, burned, composted or buried, it should be possible to get rid of 95% of the *P. noxius* on a site. Furthermore, due to the small diameter of all remaining roots, the half-life (the time needed for other soil-borne microorganisms to destroy half of the remaining inoculum) might be expected to be less than a few months. The question remains, however, is this practice pragmatic? There are at least several hundred trees (and perhaps a few thousand trees) that would have to be removed on these Guamanian sites and, at perhaps 15 minutes of labor per tree, this represents quite a bit of work. It is suggested that mapping the location of every tree in this area that might need to be removed, and calculating the cost of removals, might be a first step before deciding how to deal with this problem.

Another, challenge emerged as a result of the visit to this site and that was to determine if "Sernel" (*Serriathes nelsonii*) might be resistant to *Phellinus noxius.* This question was posed by the Guam endangered species team (GPEPP: Guam Plant Extinction Prevention Program). At the time of the visit to the *in situ* conservation area for "Sernel" it appeared that it might not be. The single remaining Sernel tree at this site is very heavily colonized by a Ganoderma root and butt rot, but there was no evidence of *P. noxius* on this tree.

One way to test this possibility is to raise *P. noxius* inoculum on 1" x 1" x 4" sections of wood in Mason jars and then strap these sections of inoculum onto the root system of saplings of the tree species one wishes to test for susceptibility. Details as to how to conduct such a trial (including the provision of controls) were run through with several individuals at the U. of Guam during this trip. Generally these tests are run under greenhouse conditions. Further details on appropriate procedures for these tests are provided by Nandris *et al* (1987) and Singh (1980).

Another way to determine the susceptibility of Sernel to *P. noxius* is to look at individual Sernel trees on other islands where they have been challenged by *P. noxius*. There are a lot of trees of this species (or at least a very close relative) growing in nearly pure stands in Saipan. An examination of a lot of these trees showed that they were, indeed, very heavily affected by *Phellinus noxius*.

Another area on Guam that that has lots of *Phellinus noxius* infection foci is the Anao Conservation Area which is being managed by Guam Forestry. Rudy Estoy is the person in charge of this area. Ashley Lehman and her Forest Inventory Analysis crew were the first to discover *Phellinus noxius* in this area. They had all attended the *Phellinus noxius* workshop which we had offered a couple of months earlier, and this helped them find the area and pick a location for an FIA plot.

During this 2015 visit we were shown the plot center for the FIA plots that this team had installed in one of these foci. We were very careful not to disturb or document anything in this plot (as this is an FIA prerogative), but then we did visit another six infection foci that were nearby and quickly mapped the distribution of dead and recently infected trees in some of these areas. It should be noted that Mario Martinez and John Horeg took GPS readings for another 23 infection foci in this general area.

The only trees that we saw that were infected in Anao were also growing on karst topography. In other words, it has same very sharp hostile (sharp) parent material characteristics that were had found at Ritidian. It seemed as if the same infection process of storm damaged roots may have occurred in Anao, as well, although here, the infection foci had obviously been active for several years and the typhoons of 2015 may just have contributed to the rate at which they are expanding.

Because the infection foci were all located on karst topography (which has a great dearth of soil), none of the trees had developed to any great size and because the *P. noxius* infection weakens the wood of infected trees so completely it would be very easy (physically) to remove these trees and their root systems from these spots as well. Still it appears that a clean-up of this site might involve the removal of perhaps 500 trees or more and their respective root systems. Is this something Guam Forestry might want to launch into? Once more, the making of a more precise map showing the location and size of all of the infected trees might be something that could help in making this decision.

One other phenomenon at Anao is worth commenting on. On one six-inch tree the mycelial sheath of *P. noxius* only extended 8" up the bole, while on a neighboring tree of the same species and size it was noticed that the mycelial sheath extended 8 feet up the bole (Figure25). A possible explanation might be that the degree of development of the mycelial sheath on a tree's bole might be linked to the locations on the lower bole where water is accumulating from stem flow during storms.

Figure27. A mini-course was given on procedures for isolating *Phellinus noxius* from infected roots or fruiting structures onto selective media. Participants from left to right are Rudy Estoy, Else Demeulenaere, Gregorio Borja III, Phil Cannon, John Horeg, and Mario Martinez.

There were three other *Phellinus noxius* activities on Guam: 1) The first consisted of six individuals trying to make isolations of *P. noxius* from the samples that we had collected in the field during the previous three days. (This was done in the Robert Schlub lab and the samples were mailed (by UOG Extension Associate Roger Brown and UOG Extension Assistant Joe Afaisen) to the Ned Klopfenstein lab in Moscow, Idaho where the molecular genetic analyses will begin); 2) a 90 minute discussion was held in the Schlub lab about which future Phellinus activities should take place on Guam, and 3) the author gave the *Phellinus noxius* power point presentation to the Guam Forestry Department in their building.

Yap-

On Yap, as on most other islands, the *Phellinus noxius* activities began with a meeting with most of that islands foresters. The author provided a presentation on what we already know about *Phellinus noxius,* and we also discussed what we wanted to get done on Yap during this particular visit. In the next two days, several *P. noxius* survey and control measures were undertaken. These will be discussed ahead. The *P. noxius* activities on Yap ended with a wrap-up session during which Yapese *P. noxius* activities that took place during this visit and activities that should take place in the upcoming months were deliberately reviewed. One other highlight of this visit was to spend some time with Sabino and Julian, the executives of Yap Cap (Yap Community Action Program) which is the NGO that is dispensing the S&PF (Forest Service) money to do additional *Phellinus noxius* survey work and management activities.

The *P. noxius* infection foci behind the forestry building was the first and last spot that we visited on this trip. We used the great example of the infection foci at this spot to educate about 12 Yapese foresters about the signs and symptoms of this disease and to discuss how this fungus is able to spread, infect and colonize and kill trees. On the last day we made a very detailed search of every tree within a 150 foot radius of the main infection center at this site. Then, each of the trees that showed sign of *Phellinus noxius* (eg Figure 4) was pushed over and then the root systems of these toppled trees were excavated down to the point where these roots were a ½ " diameter or less. A common pick was found to be very adequate for this purpose. All of this infected debris was then loaded on a truck and then Yap Quarantine officer, Andrew, trucked the debris away and burned it in the Yap Quarantine Fire Pit.

The foci behind the forestry building was the most extensive foci that we would see on Yap which strongly suggests that it is the oldest foci. Indeed, it may be the site at where this fungus first gained ingress to this island nation. In separate conversations, I asked Puis and Francis both how they thought the disease might have started there. Independently, they told me almost exactly the same story. Initially the forestry building was once the main feed station for the animals of Yap. This was back when it was felt that some cattle, pig and chicken populations would be needed to support a human population on this island. Unfortunately, the soils of Yap have exceptionally poor soil chemistry (see Chapter 6 on fertilization) and this made it difficult to raise many feed crops. So, in order to feed these animals, Yap had to import vast amounts of animal feed in ships and much of this feed had to be loaded onto pallets. Once the feed was off-loaded in Yap many of these pallets were discarded behind this feeding station (and indeed, even today, one can find old pallets laying around this station). Some of these pallets may have been constructed on other islands using *P. noxius* infected wood and, as such, the abandonment of these pallets on Yap could have been an easy pathway for the transfer of *P. noxius* from these other islands to Yap.

The next place we went to check for *P. noxius* was near Val's village. He had seen a number of trees that had symptoms similar to a black sock around their base, but when we arrived there and checked out about 10 trees that Val thought might have *P. noxius*, it was determined that all of these trees were actually healthy and the black coloring was perhaps caused from accumulation of water from stem flow, but definitely was not *P. noxius*.

We then went to the path that leads to Andrew's Village and walked about one mile down this path. Two years earlier, Andrew and I had spotted a tree in the middle of this path that had clear symptoms and sign of *P. noxius*. At the time of this present visit that particular tree was no longer present (probably it had died, become rotten and had been cleared from the path), but we did find three other small *P. noxius* infection foci nearby. Significantly each of these foci were found initially only because there were one to three dead trees on each of those spots. It was usually only when we began to examine the boles of these dead trees very carefully that we were able to find evidence of the black mycelial stocking. Usually this sign was developed most obviously on the underside of the root system, so toppling and excavation of the tree's root system was commonly needed to verify the presence of the fungus.

The last place we went to visit was near Francis' house. Initially we were going to look for *P. noxius* amongst a group of "poison trees" that Francis had noticed were dying, but when we got to his property he remembered that there was another more accessible area (close to the entry gate) that also had the disease, so we went there and found another few trees that did, indeed, have the *P. noxius* butt rot. We discussed survey procedures to see which other trees at this location might be also be infected. We also discussed phytosanitary measures that could be used to get rid of the disease. The phytosanitary methods that we agreed on for this site would be the same as the ones we used for the *P. noxius* infection foci behind the forestry building.

Saipan-

Saipan was the first place for *Phellinus noxius* to be found in the western Pacific. Dr. Jack (Juaquin) Tenorio was an eager entomologist at the time and because he was exceptionally energetic he was appointed to be in charge "of all plant industries in Saipan". During his tenure in this position, the dieback of the flame trees (Saipan's national tree) was brought to his attention. In those days the US Forest Service had appointed a forester to be in charge of forestry on that island, his name was Mike Robinson. Jack asked Mike if he could help and Mike, in turn, asked Chuck Hodges, an extremely knowledgeable forest pathologist then stationed in Hawaii, to come out and have a look. Chuck did and the result was the 1986 publication by Hodges and Tenorio (1984). One of the first places they studied was a row of infected flame trees (*Delonix regia*) in a lot adjacent to the International Airport.

Figure28. At this line planting of flame trees (*Delonix regia*) along the Airport Road, seven trees in a line had been killed by *Phellinus noxius* which had grown from the root system of one tree to that of the next. Then, these rotten root systems had insufficient strength to keep their stumps upright during a recent typhoon. Hundreds more flame trees have also died in this general vicinity dating back to the 1980s. In the foreground the hibiscus growing nearest the closest stump has also contracted the disease by root to root contact and is slowly dying. The roots of hibiscus plants at the far right are not yet infected (but soon will be).

Of all the islands in the Western Pacific, Saipan is the place where I have seen the most Phellinus. On my first trip out, I found the disease foci that Hodges and Tenorio had identified near the airport within 30 minutes of landing (see Figure 28) and I have returned to that area maybe 5 times in subsequent years either to make more studies or to share the site as a learning tool with collaborators.

As a Forest Pathologist, I feel a little lucky in Saipan. If we had so many dead trees in the mainland, these would have been carted off and disposed of years ago. Here, however, they have been allowed to sit where they dropped for years and, as a result, it is pretty easy to reconstruct the movement of the fungus from one root system to the next on this site.

Another site that I have visited on several previous visits to Saipan is a site I have nick-named “Angry Sisters”. At the time of my first visit to this site (in 2010) there were two houses that were on big adjacent lots. Then, these two houses were nicely separated by a beautiful stand of mixed hardwood and palm trees that would have occupied about two basketball courts end to end. At that time, a couple of trees on one side of this stand showed the mycelia crust of *P. noxius* and I made the prediction that one day, in the not too distant future, this Phellinus could spread and take over the whole stand. That day has come much faster than I had predicted. Now, just five years later, the entire stand (except for the palms) has been killed by *Phellinus noxius*, the trees have fallen over and are now covered in vines (See Figure 29) By our calculations, this fungus may have been growing through this area at almost 20’ per year. (Note: this area also took a hit from a typhoon about 6 months earlier).

Figure29. The forest stand at “Angry Sisters” that has been almost completely cleaned out by *Phellinus noxius* in just five years. The only trees remaining are a few palms and one *Serrianthes* (rear center); but an examination of the base of this *Serrianthes* showed that it had a large mycelial sheath climbing up its base, so it, too, will be dead in a matter of weeks or months.

Another area we visited was at the Art Guerrero farm, near Kagman. Two years earlier only two trees in a stand of 20 were infected with *P. noxius.* During this visit, however, all but two trees in this little stand had been killed by *P. noxius*. There were also about eight sprouts of breadfruit that had come up from root sprouts of a diseased trees. Unfortunately, these root sprouts were also entirely girdled by the mycelial crust of *P. noxius* (Figure 30), so they had not escaped for long.

Figure30. The telltale mycelial sheath of *Phellinus noxius* rising around the base of an infected breadfruit sprout at the Art Guerrero Farm. This sprout will be alive a few more months, at most.

The other area where we spent a fair amount of time was at the Dr. Ada house lot. Work on this site was serendipitous. On a previous trip, with Sid Cabrera, we had found a lot of *Phellinus noxius* on trees up in Vic Guerrero's neighborhood, so, on this trip Jason Tenorio and I had gone back to this area to have another look and make additional observations. However, during this visit, we found that the going was extremely difficult. A super typhoon had passed through this area 6 months previously and knocked over thousands of trees, so these were kind of stacked up on each other. Then, since the storm, invasive vines had grown up and over these fallen trees. Currently these vines were anywhere from 3 to 15 feet deep. Because of these circumstances, it was taking us five minutes to fight our way through the vines to get to the base of a single tree and then another five minutes to clear the vines at the base of that tree to the point that we could adequately examine it for the presence of *P. noxius*. After spending a few hours doing this, and finding no infected trees, we were frustrated. Fortunately, Jack Tenorio had told me about an old Japanese Arboretum that was nearby, so we tried go there to check it out. There was a locked gate at the arboretum, so we could not get in, but nearby there is a lot belonging to Dr. Ada. This lot, which is almost exactly the size and shape of a football field was in the process of being cleared of all brush and vines right down to ground level, but all living trees were being left behind. This provided us with a golden opportunity to examine the bases of 150 trees right down to the groundline. We were astonished at how many trees were infected with *P. noxius* (see figures 31 and 32).

Figure31. At the Dr. Ada house lot, the brush and vines have been removed from about one acre of land all the way down to the ground line. This facilitated studying the base of about 150 trees, many of which were infected with *P. noxius*. Jason Tonorio made the call on whether or not each of these trees showed sign of *P. noxius*, or not, and the author estimated their diameter at breast height and mapped them as shown in Figure 32.

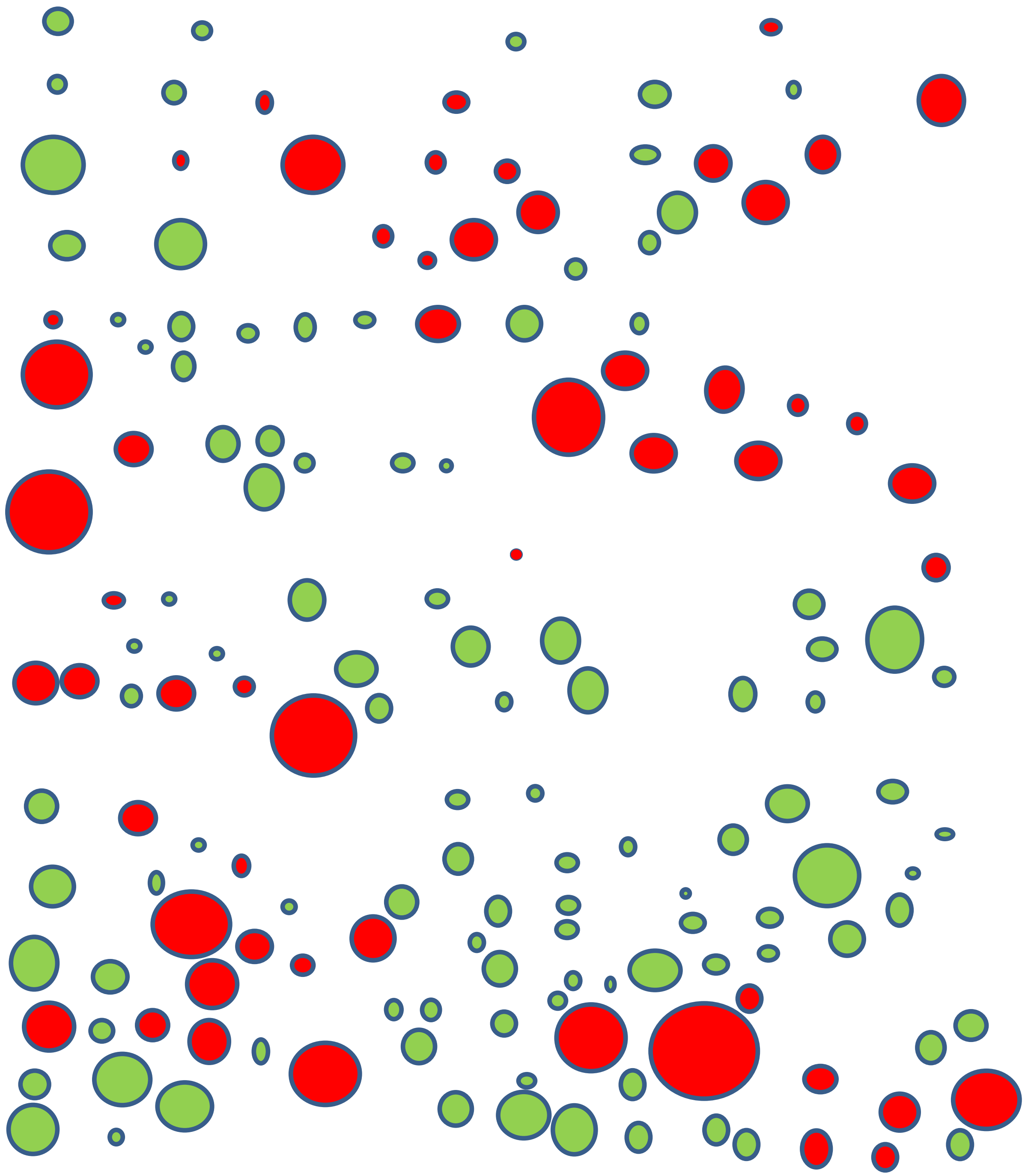

Figure 32. The distribution and diameter of healthy (green circles) and Phellinus-infected *Serriathes spp.* trees (red circles) on a Navy Hill property recently cleared of all understory brush and vines in suburban Saipan. The largest circles represent trees with diameters at breast height of 36" the smallest trees have diameters of 4". Green circles indicate trees that appeared healthy; red circles indicate trees that showed sign of being infected by *Phellinus noxius*; some, but not all of these trees were already completely dead. The plot center is at N15°17.814' E 145°41.923.

Rota and Tenian

I was unable to visit Rota on this trip because a super typhoon was supposedly going to arrive almost exactly at the same time that I was scheduled to arrive on that island. However, while in Saipan, I did have the great fortune of having dinner with “Jack”, Joaquin Tenorio, the co-author of the first article about this fungus (Hodges and Tenorio, 1986). Dr. Tenorio drew me a map of two locations where *P. noxius* could be found in Rota (see Figure 33). Once again, the disease is exceptionally close to an airport, is this coincidence or a trend? Dr. Tenorio also mentioned that they had never found the disease on Tinian, despite searching there, as well.

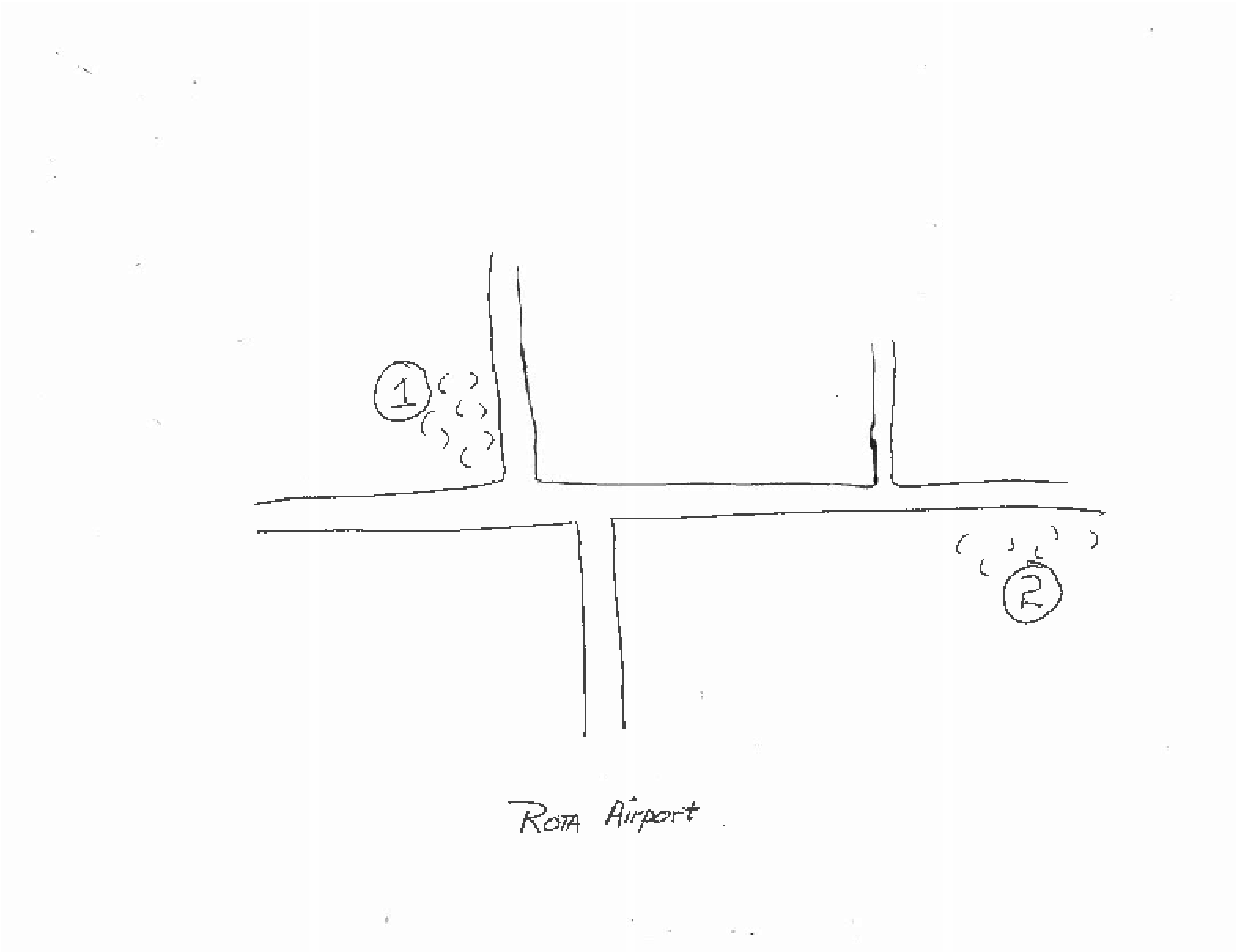

Figure33. Sketch by Jack “Juaquin” Tenorio showing the two places where he has found *Phellinus noxius* near the Rota Airport in the past.

Table 2. A list of locations from which *Phellinus noxius* samples (fructifications or infected wood) were collected in FSM, Guam and Saipan (during the 2015 pathology trip to Pacific). Isolations were made from these samples onto agar plates on these islands and then sent to the Ned Klopfenstein lab at the Rocky Mountain Station in Moscow, Idaho.

Saipan

Airport Road. *P. noxius* N15°07.648' E145°43.485' Flat ground. Site of original find by Hodges and Tenorio (1986).

Airport (Cerrena a possibility?) N15°07.648' E145° 43.485' This wood had previously been colonized by *P. noxius* but is now occupied by a fungus with a Cerrena-like conk. Is this a possible biological control agent.

Angry Sisters *Phellinus noxius* 15°09.891' E 145°43.129'; Elev.73 feet. The ground here is nearly flat ground; but this site accumulates some runoff during rains. Fungus is unbelievably aggressive here, maybe moving 15-20 feet/year.

Dr. Ada's lot on Navy Hill. *Phellinus noxius* suspected. N15°17.814' E 145°41.923'; Elev. 300 feet, 30% slope; 35% of the *Serrianthes nelsonii* (a distant relative of the flame tree) trees have *Phellinus noxius*.

Farm of Art Guerrero, Near Kagman town. N 15°10.262; E145°96.374; Elev. 251 feet; flat ground; 100% kill by *P. noxius.* While just a few trees were dead in 2013, they are all dead now.

Guam

Anderson Airforce Field in NW Guam N13°38.937' E144°51.779'

Anao conservation area, 20 different infection foci were located in this area.

IPAN one infection foci was located at this site.

Kosrae

Yela Reserve N05°32.574'; E162°95.232'

Yela Reserve N05°32.597'; E162°95.235'

Yela Reserve N05°32.597'; E 162°95.235'

Tafayat N05°31.287' E:165°0187'

Erick Waguk's farm N05°31841'; E163°02782'

Yesron N05°28913; E162°97241'

Pohnpei

Gibson’s farm, original *P. noxius* site for this island; N06^{o} 49435’; E 158^{o}10222’ Elev. 100’

Joab’s farm (Salawuk). First stop up the Six Waterfalls Road Elev 150’ (1/4 mile from Gibson’s farm)

High elevation site (at the top of the Six Waterfalls Rd (Elev 700 ‘) (1/2 mile from Jeremiah’s farm)

Jeremiah’s farm a breadfruit next to the house and a big stump nearby N06^{o}1555239’; E 158^{o}10396’

Source of Merremia leaves with anthracnose (Cupid’s Restaurant) N06^{o}50812; E158^{o}10724

Yap

Somehow we forgot to take a GPS unit with us every day we were out (perhaps because I was there mainly on holidays and weekends). However these locations are easy (for me) to find on a map.

Phellinus noxius-from right behind the forestry building; slightly rolling landscape.

Phellinus noxius from the path leading to village of Andrew Farlotz. In 2013 there was just one tree that showed active Phellinus. When we visited this year, that tree had virtually disappeared (just a little bit of stump left, but there were several newly infected trees). Note: one has to look hard to see the infection on these trees; just the bottoms of the root systems were blackened. I seemed that the infected trees were wearing black ballet slippers on their roots. Side-slope.

Phellinus noxius from the Francis Ruegorong family estate. Moderately steep ground; side-slope.

A Colletotrichum-like fungus isolated from piper betel leaves in the relatively humid betel nut region of Rull. Some of these piper betel vines had lost 40% to 90% of their leaves due to the anthracnose caused by this fungus.

A Colletotrichum-like fungus isolated from piper betel leaves on the relatively drier coast of MAAP. The presence of the fungus was obvious, but nowhere nearly as bad as at Rull, and where the betel nut palms had been deliberately thinned (allowing sunlight and wind to penetrate down to where the piper betel is climbing the tree), the piper betel leaves appeared to be very healthy.

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Chapter 2 Advances towards understanding the etiology of *Phellinus noxius* and natural and artificial control measures

Learning about the distribution of *Phellinus noxius* and the impact it is having on forest trees in these Pacific Islands is just one part of the reason for studying this fungus. The real reason that we do anything in the Region 5 Forest Health Protection Unit of State and Private Forestry of the USDA Forest Service is so we can help minimize the negative impacts that a pathogenic organism, such as *P. noxius*, can have on the health and vigor of the forests found in this region. Prior to and during this trip three general sources of information were consulted to help figure out how to most cost-effectively manage this disease:

1) **Publications.** There are actually dozens of articles that have been written about control efforts that have been attempted for *P. noxius.* Most of this work has been done in areas of the Pacific which are further to the south and west of our area of study (eg Australia);
2) **From local island lore**. For decades *P. noxius* has been recognized by local populations of FSM as a menace to tree health. As a result, some attempts have been made to use local materials to try to kill off the mycelial crust of this fungus when this has been found growing up the outside of a tree;
3) **From observations made during this trip.** Several possible biological controls appeared to be competing with or displacing *P. noxius* from colonized tree boles.

Indeed, each of the 18 different Phellinus management efforts that were tried during this trip (these were all documented in Chapter 1) was based on information from one or more of these three general sources and was simply aimed at tipping the balance of the disease triangle (which has the pathogen, the host and the environment at the three vertices) in such a way that natural control possibilities could be favored. In the future we will have to return to the locations where these Phellinus management measures were attempted to assess their relative effectiveness.

What was especially of interest and especially encouraging during this 2015 visit, was that there seemed to be a lot of naturally occurring antagonists of *Phellinus noxius*. For instance in several locations *Phellinus noxius*- killed trees were being overridden by termites (Figure 34). Whereas in other locations, wood ants were tearing apart the inoculum (Figure 39) and in still others there was a prevalence of unidentified wood borers (Figure 38) that were opening up wood colonized by Phellinus to saprophytic fungal species. One isolation that was made, in a *P. noxius*-killed-and-colonized flame tree, was of *Earliela scabrosa*, a fungus known for its capacity to overtake several species of root-rotting fungi (Figure 35) (Peng and Don, 2013). There was also evidence that some saprophytic wood decay fungi were able to invade wood that had first been colonized by *P. noxius* and, by doing so, displace this *P. noxius* (Figure 37). All of these natural mechanisms could tremendously reduce the duration that *P. noxius* could continue to exist in as viable inoculum in the wood of a stump or a log. And, they could probably reduce the capacity for infected logs to produce *P. noxius* sporocarps. Based on these kinds of observations, it is suspected that some degree of control of *P. noxius* might be achieved by favoring some of these organisms that are antagonistic to *P. noxius*. Of course, the best antagonistic organisms to use and the best ways to employ them, will have to be worked out through careful studies that are more deliberate than anything that was attempted or documented during this trip. And, of course, it will be very important to determine if any of these potential biological controls might also introduce any negative consequences. Note: Discussion on the best way of experimenting with any of these "biological controls" is anticipated and will be appreciated.

(a)

(b)

Figure 34a and **b.** Termites show that they can invade both the boles **(a)** and the butts of trees killed by *Phellinus noxius* and thereby reduce the capacity of these boles to sustain *P. noxius* inoculum.

(a)

(b)

Figure 36 a and **b**. Top view **(a)** and lower view **(b)** of a fungus found growing on a flame tree killed by *Phellinus noxius* in Saipan. Isolations from this fungus, and subsequent molecular genetics work, shows that this is *Earliela scabrosa* a saprophytic fungus known for its capacity to displace butt-rotting pathogens.

Figure37. A Ganoderma (or Earliela) species (which shows up as having a broad white brim in this picture) is shown growing right out of a stump that has been attacked and killed by *Phellinus noxius* (as evidenced by the thick black mycelial crust covering the trunk in the middle of this picture). Ganoderma fungi are generally weakly pathogenic on several tree species and Earliela are only saprophytic, but if they can colonize a tree that has already been killed and occupied by *Phellinus noxius*, then they may also be helpful for substantially lowering the inoculum potential of *P. noxius*.

Although the above evidence might suggest that *Phellinus noxius* has many natural enemies, we have to remember that *P. noxius* also has a phenomenal capacity for growth and an omnivorous appetite for many different species of living trees. Thus it seems to have first dibs at the generous smorgasbord of photosynthates that a typical wet tropical forest provides and can quickly build up enormous levels of inoculum.

Figure 38. Pin-hole borers (the very small holes) and other insects (the larger holes) work their way easily and preferentially though wood that has been colonized and weakened by *P. noxius*.

Figure39. Wood ants pulverize the *P. noxius* inoculum that once occupied this stump. Many other species of insects and fungi can now follow easily and completely destroy the Phellinus.

In Chapter 1, some observations were made about how *Phellinus noxius* is able to operate and what factors might promote or limit its' capability to operate as a pathogen. The pathogen, under apparently optimal conditions, seems to be able to expand existing infection foci quite quickly. In American Samoa the fungus spread 15 feet a year, on average, for a 12 year period, while progressing from one root system to the next, down a line planting of Kapok trees (*Ceiba pentandra*). At the "Angry Sisters" site in Saipan the rate of root to root spread for this fungus has been estimated at 20 feet per year over a five year period (Figure 29). These growth rates are considered to be especially high because of environmental conditions favorable to the fungus (over 15 feet of annual rainfall in A. Samoa) and because of the especially susceptible nature of some of the hosts (kapok has low density wood and essentially no extractives in its heartwood), still, compared with growth rates of other root and but rotting basidiomycetes, they are truly phenomenal.

As an aggressive pathogen, once *Phellinus noxius* gains access inside a trees defenses, we often find that whole sections of the tree bole and root system quickly become colonized by this fungus, and then, once in the wood the fungus does something else really amazing. It essentially seals itself, and all the wood it has colonized, off into small, dice-sized- segments so that no other organism can get in and kill it. The way it forms these seals is by means of constructing zone lines which are basically concentrations of dark, dead *P. noxius* hyphal material matted together and laid out in a giant honeycomb fashion so that collectively protects the live Phellinus mycelium within each of these honeycomb sections (Figure 40).

Figure 40. Section of a root colonized by *Phellinus noxius* in American Samoa and showing exceptionally dark zone lines (photo courtesy of Fred Brooks). Zone lines are found where *P. noxius* has infected trees and logs in all of the Pacific Islands. However, on islands in the Western Pacific, these zone lines are often fainter and more orange in color.

Some evidence suggests that *P. noxius,* if undisturbed by mechanical or by biological controls, could continue to exist in these fortified units of colonized wood (protected by zone lines) for ten years. This would often be enough time for roots of neighboring trees to grow into the proximity of these refuges of inoculum and become infected themselves. An obvious means of managing this fungus, therefore, is to destroy these lumps of inoculum before they can cause additional infection. In theory, this could be done either by physically breaking up these lumps of inoculum into much smaller and relatively defenseless units of wood which which could subsequently be over-run by fungi or insects (such as those presented earlier) or by chemically changing the soil in the rhizosphere (for instance by adding urea or by changing the redox potential by flooding). Whichever methods are tried, their impact should be monitored to determine how they have destroyed the *P. noxius* inoculum.

However, during the course of this visit, one major wrinkle was discovered which may have a countervailing impact on this relatively simple approach to managing *P. noxius.* Under some conditions, at least, we are just now finding that *P. noxius* can also produce incredibly massive numbers of spores. One of the conditions under which this can happen is during or soon after heavy storms. Perhaps the most sobering find on this 2015 trip was that almost every *P. noxius* -infected tree that we pulled out of the ground in Guam had resupinate sporocarps on the lower side of its main roots. So far, there is little understood about the importance of these subterranean resupinate sporocarps. There are protocols for studying the formation of sporophores, the ways the spores spread from them and the conditions under which their spores can, in turn, infect previously uninfected trees in new locations and then develop new infection foci. Some additional studying and consulting needs to be done in order to figure out the best method for conducting these studies. One thing that does seem obvious already is that much of this work will need to be done right after a big storm because at this time there will be more spores being produced and the potential for development of new infections will be greatest. It is obvious, therefore, that the authors next trip to the region will have to be in the middle of another super-typhoon season.

In sum, it is premature to make many statements about new infections being caused by *P. noxius* spores, but obviously, if a large number of new infection foci can start as a result of spore dispersal, the previously explained mitigation program, designed to manage a root disease spreading mainly by root to root spread, will need major modifications.

A final note: This topic is far from complete; more information needs to be collected, eventually a much more complete document will be developed to discuss *P. noxius* control measures.

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Chapter 3 Colletotrichum-caused anthracnose of Betle Piper leaves in Yap

In Yap, Betle piper (*Betle piper,* Family Piperaceae) vines are grown on the trunks of the betle-nut palm tree (*Areca catechu*) and generally there are a few single strands of beetle piper vines that run from the base of the palm up into the crown of the palms. A healthy betle piper vine, will have oval leaves that are 5" in diameter. These leaves can be borne singly or in small clusters. With a healthy vine, these singles or clusters of betle piper leaves will be sprouting from a vine at 8 inch intervals from its base to its top (Figure 41b). These betel piper leaves are extremely valuable because they provide the container for holding the betel nut chew; the farmer can sell them for $4.00 for a packet of 50 leaves. Collectively these leaves and the betel nut from the palm are worth millions of dollars annually to Yap.

Unfortunately, a few years ago, an anthracnose-like fungus was found forming a black spot on these betel nut leaves and this spoils the leaf for prime usage. The sign and symptoms of this disease (Figure 41a) are very similar to those associated with the fungus *Collectotrichum capsici*. In 2013 and again in 2015, a few isolations were attempted from affected Piper beetle leaves. Unfortunately, all of the isolations made to date have suffered from contamination.

Figure41. Piper beetle leaves with (on left) and without symptoms of *Colletotrichum capsici* leaf spot.

Additional isolations will have to be made, but on the next visit I will try to have appropriate selective media and find a place to operate that can be sterilized better than my hotel room. In the meantime, I will continue to tentatively assume that the involved fungus is *C. capsici*, and recount some observations that we were able to make this trip during visits to two of the main piper beetle production locations in Yap. It is hoped these observations may prove insightful for understanding the environmental conditions and other factors that are conducive for the development of this fungus.

MAAP Coastline

The first place we visited was in extreme north Yap on the northern coastline of MAAP. There a collaborating farmer allowed us to see all we wanted in his betelnut/betel piper plantations. Very interestingly, this farmer had two betelnut/betel piper plantations that were hardly separated at all and even were on the same flat terrain. The one difference between these plantations was that the first plantation had not been thinned while the second one had been thinned. During this thinning about ½ of all betelnut palm trees had been felled. The difference in the health of the betel piper leaves was immediately obvious. Where the betle palms had been thinned, there was much more sunlight entering into the stand and the leaves were quite healthy (Figure 42); whereas in the unthinned stand there was perceptibly more anthracnose.

Figure42. Sunlight pours into the understory of a recently thinned betelnut palm plantation in MAAP. Under these circumstances, at this location, the leaves of the betel piper appear to be quite healthy.

Rull

The second place we visited was in Rull. This is actually in the center of betelnut production area for Yap. Unfortunately, even though these betelnut palms were rather widely spaced, many of the leaves on the betel piper vines growing up their trunks were seen to have the black anthracnose spots and many other leaves were missing. In some cases it appeared that the leaves had become so heavily infected, they had simply abscised, however, there was some leaf harvesting going on, too, so it was hard to figure out exactly how much diseased-caused abscission may have taken place. (Note: when leaf infections cover more than about 50% of a leaf surface, the host plants will often form an abscission zone at the base of the petiole of that leaf; this allows them to cast off the leaf and cut their losses).

Everyone I spoke with indicated that Rull was a more humid place than the betlenut area of the MAAP Coast so this may why the betle piper anthracnose problem is so much greater in Rull than in MAAP.

In terms of possible controls, it is unclear whether adding addition space between the palms at Rull would help significantly; on a sunny day, there is already considerable sunlight reaching the bases of these palms in Rull

On the other hand, sterilizing the tool used harvest the leaves between cuttings might be beneficial. The tool used for harvesting these leaves basically consists of a kitchen knife lashed onto the end of a 15- foot-long bamboo pole (Figure 43). As the practice is currently conducted, the same knife edge comes in contact with the petioles of diseased and healthy piper beetle leaves alike. This might be a factor accelerating the spread and amplifying the impact of this disease. Sterilizing the knife blade between cutting leaves on different piper betel vines might be a wise practice, especially when going from a highly infected vine to one with less or no infection.

Some possible means of achieving this sterilization are by soaking the knife blade in a solution of one of the following disinfectants for about 5 minutes[1]:

Household bleach (ex: Clorox): 25% solution (1 part bleach + 3 parts water)
Pine oil cleaner (ex. Pine-Sol): 25% solution (1 part cleaner + 3 parts water)
Rubbing alcohol (70% isopropyl): 50% solution (1 part alcohol + 1 part water)
Denatured ethanol (95%): 50% solution (1 part alcohol + 1 part water)
Trisodium phosphate (Na_3PO_4): 10% solution (1 part Na_3PO_4 + 9 parts water)
Quaternary ammonium salts: use as directed on product label
Household Disinfectants (Lysol, etc): full strength

After the soaking, the disinfectant must be completely washed off using clean water and then the knife should be allowed to dry. Failure to get rid of the disinfectant could mean that the disinfectant could aggravate the healing process of the vine following the cut. Note: the knife blade needs to be kept very sharp, as well, because pitting of the knife edge could result in harboring unwanted bacteria. The disinfectant solution should be replaced frequently (about once every 20 vines attended).

1) Adapted from Lamborn, A.R. Disinfecting pruning tools. Univ. of Florida. http://baker.ifas.ufl.edu/Horticulture/documents/DisinfectingPruningTools.pdf

Figure43. The way piper beetle is harvested is by lashing a sharp knife onto a bamboo pole and then raising this pole up to where the leaf is to be harvested. The petiole is then swiftly cut. To prevent spread of Colletotrichum it may be important to sterilize the knife when going from one vine to the next.

Figure44. Julian, CFO of the YapCap NGO prepares for a chew of betelnut. He claims the anthracnose caused by the Colletotrichum (the black spots on these leaves) does not bother him so, right there on the spot, he was designated as a semi-effective biological control agent for this disease. Note: YapCap graciously agreed to manage the mini-(USDA Forest Service) grant to do *Phellinus noxius* work in Yap. We were very pleased with their collaboration.

Chapter 4 Vines in the Pacific islands and possibilities for their control

Conscious that there are others, like Dave Bakke (of State and Private Forestry, R5, USDA Forest Service) that spend large segments of their time trying to figure out ways of managing vines in the islands of the Western Pacific, the author did not involve himself very heavily in studying the influence of invasive vines on the islands visited during this trip. Never-the-less, as these vines are rapidly covering the landscapes of so many islands in the Pacific, it is very difficult to ignore them. The Island of Weno, in Chu uck is currently the island that is most affected by these vines and the most prevalent vine there of all is *Merremia peltata* which covers about 80 % of the western flank of that island. Merremia is also very prevalent in Kosrae and Pohnpei, although not quite so dominant over these two islands. In all of these islands, the vines may be 5 to 20 feet deep, and can cover almost anything (houses, trees, crops etc). All other plant life (except for the palms) becomes smothered and dies beneath these vines.

Figure45. Erick Waguk points to the out-of-control growth of the Merremia vine. He owns many hundreds of acres of land covered with these vines on Kosrae and, although he is a very hard-working man, these vines are just too much to deal with using hand labor.

Merremia, like most of the other vines on these islands, are newcomers and, since they have not yet encountered any resistance (or at least not much) they have tended to grow as fast as they are physiologically capable, which is often three feet or more each day. During this trip, the author did keep an eye out for potential biological controls of these weeds and did find some anthracnose diseases of Merremia that appeared to just be getting started on Pohnpei (see Figure 46). On Guam, there was also a rust disease on the mile a minute weed that seems to have already become well-established bio control. On returning to the US, the author spent some time looking for information on these vines and their bio controls and found out that there is already a lot of information these topics. There are also many other islands in the Pacific where there has been very positive experience controlling these vines with herbicides.

Suffice it to say, where there is a will, and maybe some funding, it should be possible to greatly diminish the deleterious impacts of these vines.

Figure46. An, as-yet, unidentified anthracnose-causing fungus severely impacts Merremia vines growing up the slopes just below Cupid's Restaurant in Pohnpei.

Chapter 5 Fertilization of forest plantations on acid soils of Yap

In the trip report prepared following the 2013 trip to FSM the author wrote six pages documenting and explaining the extremely difficult soil conditions that are encountered principally in the upland portions of Yap and Palau (Cannon, 2014). The main problem is that many of the upland soils on these islands are extremely acid and usually have phytotoxic levels of aluminum saturation. As a consequence, it appears that no useful plants or trees can grow well on these soils, unless, perhaps, these soils can be modified. In that report previous attempts to improve this situation in Palau (through light mulching and some reef-based fertilizers) were reviewed at the sites where they had been applied but these treatments were found to have been ineffective. More aggressive fertilizations were suggested as a possible solution (Cannon, 2014).

Figure47. An upland soil on Yap. The soils are so acid here, and the aluminum saturation (of the bases) percentage is so high, that bauxite nodules lie exposed on the surface of this soil. Despite this being an area that receives over 2,000 mm of annual precipitation, almost no plants can be seen growing in this area.

Figure48. Puis demonstrates a plantation that was attempted on slightly better soils than those shown in Figure 47. Some mulch was applied at this site, but no fertilizer. The survival rate is OK, but growth is still exceptionally slow.

During this present visit, one Saturday was used to install a very basic fertilizer experiment in a young existing *Acacia auriculiformis* plantation.

Puis and I found a good plantation for this experiment. It is located by traveling to the borderline with MAAP and then taking the left fork at the sawmill store (instead of heading on to the north MAAP coast). Soon after making this turn there will be a large water tank will be one's right. One then travels about a quarter of a mile down this road to another, less obvious, turnoff to the left. One takes this fork, too and then parks the car immediately, the study area is on the left, perpendicular to the road.

The study area consists of a small plantation of *Acacia auriculiformis* most of which were between 4 and 10 feet tall at the time this experiment was installed. The trees were planted five years ago, but they are still small because there is essentially no soil at the site, mainly one sees bauxite nodules at the surface; these are comprised of almost pure aluminum.

The test we wanted to set up is called a "t" test. It is very simple. Basically we began this test by identifying 15 pairs of neighboring trees in such a way that each member of a pair of trees was very similar in size and health to the other member of that same pair. Then we numbered the two trees in each pair, for example 2 and 2', and made a flag with these numbers on them to tie on to these trees.

Next, we hoed down any grass or weeds that were within four feet of both trees in a pair and then we applied fertilizer to the tree of that pair that had been given the prime number. The fertilizer that was applied was "Miracle Grow" which has the formula (Nitrogen (18%), Phosphorus (24%), soluble K (18%), Copper (0.05%), Iron (0.10%) and Zinc (0.05%). The amount of fertilizer that was applied was 0.6 lbs per tree. The way this fertilizer was applied was to first open three slits in the ground in the area of that trees drip line using a spade and then insert about 0.2 lbs of this fertilizer into each slit. The slits were spaced 120° apart around the tree. Following these applications of the fertilizer, a small amount of soil was pushed over the top of each slit so the nitrogen would not volatilize and escape.

Figure49. One of 30 *Acacia auriculiformis* trees that has been prepared for the fertilizer "t-test". The weeds growing within four feet of this tree have been cut and piled for mulch. Another tree of the exact same size and having the same site preparation was selected to serve as this tree's "pair". For each pair, one of tree got the fertilizer, as described above in the text, the other did not.

Next, we measured the height of the trees to the nearest inch and the diameter (at breast height) of each of these trees to the nearest tenth of an inch. There are 30 trees in the experiment (15 pairs of trees). The results of these initial measurements are shown in Table1.

Table1 Diameter at breast height (in inches) and height (in feet and inches) of 15 pairs of trees at the initiation of the MAAP *Acacia auriculiformis* fertilizer test near the Water tank at the sawmill fork (November 2015).

Tree #	Diameter	Height	Tree #	Diameter	Height
1	1.6”	9’4”	1’	2.2”	10’6”
2	1.1”	7’6”	2’	0.9”	7’6”
3	1.5”	7’10”	3’	0.2”	5’9”
4	2.7”	11’5”	4’	2.4”	11’ 1”
5	1.8”	8’6”	5’	1.6”	8’6”
6	0.9”	7’8”	6’	0.9”	7’2”
7	0.9”	6’6”	7’	0.8”	8’2”
8	0.2”	5’2”	8’	0.2”	5’1”
9	0.00	3’6”	9’	0.00”	3’2”
10	1.8”	9’6”	10’	1.5”	7’8”
11	0.9”	7’4”	11’	1.1”	8’ 0”
12	1.3”	7’6”	12’	0.8”	6’3”
13	0.9”	7’10”	13’	1.1”	8’0”
14	0.1”	4’10”	14’	0.0”	3’2”
15	2.8”	11’0”	15’	2.0”	9’8”

It is reasonable to assume that if there is going to be response to this fertilization it should show up in 6 months. Thus a first measurement of this experiment should probably be made in about April of 2016. The amounts of growth can then be found for the diameter and height of each tree in this experiment by subtracting the measurements shown above (from Nov. of 2015) from the future measurements for height and diameter of these same trees. The Analysis of Variance for t tests can then be used to determine if any differences in growth rates are statistically significant.

If Puis can arrange to get the height and diameter at breast height measure for all of the trees in this experiment, then the author will gladly be willing to do the statistical analysis and, in collaboration with Puis, co-author a report on the impact of this fertilizer.

References

Cannon, P.G. 2014. Forestry possibilities for acid soils in upland portions of Yap and Palau. Pp 70-75. In: P. Cannon ed. Forest Pathology in Micronesia, Sept 3013. Trip Report. 84pp.

Chapter 6 The situation awaiting a potential nursery course in Chuuk-

Because Diane Haase and J.B. Friday were in the process of getting ready for their trip to Chuuck soon after when this pathology trip was over, all information that I thought would be useful to them was transmitted to them directly by telephone calls or emails. The current condition of the forestry nursery in Weno, Chu uck is shown in Figure21. The condition of the forestry nursery in Tenowas is shown in Figure50.

Figure 51. Basiente (on the left) and Julian discuss plans for the forestry nursery in Tenowas. At the time of this visit, there were no tree seedlings under the shade cloth, but there were several vegetables being grown there. Also, along the back fence a lot of weeding and soil cultivation is taking place; eventually thousands of coconut trees are to be produced in this space according to Julian. When leaving Chu uck, a casual airport conversation with an Australian biomass engineer suggested that hundreds of thousands of new coconut trees may be needed for this island. There are plans for building a biomass power plant on this island that call for coconut hulls as the main fuel.

Chapter 7 The situation awaiting a potential chain saw/arboriculture course in Saipan

Because Keven Eckert was in the process of getting ready for his trip to Saipan right when this pathology trip was over, all information that I thought would be useful to him was transmitted to him directly by telephone calls or emails. Kevin will probably be asked to find chain saw solutions for situations such as the ones shown in the pictures that follow. On some parts of Saipan, every tree was affected by the Super Typhoon Soudelour and many to the point where their complete removal might be the only pragmatic solution.

Figure51. A tree house near the Ada Estate on Saipan. Many branches were broken in this tree as a result of Typhoon Soudelour, the roughest typhoon to pound Saipan in 30 years.

Figure53. A very common scene in Saipan at the time of the trip. Many big trees have been stripped of all their branches and foliage and many trees had been toppled completely. The vines rushed in during the weeks and months following this destruction to take advantage the sunshine pouring in.

Figure54. The root systems of these Casuarina trees held the coastline of Saipan largely intact, but the Casuarina trees that remained standing have been stripped of most of their branches.

Although a tremendous amount of trees in Saipan were destroyed beyond all chance of recovery, and could therefore be removed, there were also a great number of trees that had lost a lot of limbs (and most of their foliage), but appeared to be making at least a partial recovery. It is not known what their eventual fate might be. Will they continue to recover and eventually put out full crowns or will they just malinger along for a few years and then die. In other words, should a wait-and-see policy be adapted? A reasonable study would involve marking trees or stands of trees for observation. Documenting the condition of each tree at that time of initiating the study and then returning to that tree once every six months or so for a reassessment. If the condition of the tree deteriorates, it could then more justifiably be removed. On the other hand, Kevin may be able to make the call on many of these trees without any waiting or a study. He has been involved with dozens of chain saw cleanup exercises following hurricanes in many parts of the tropical world already.

Figure55.The the prospect for survival of some of the trees in the American Memorial Park were considered marginal at the time this photo was shot. Should some of these trees be marked for wait-and-see, or could Kevin's expertise help decide which of these trees have no chance of recovery? Also, for those that might be saved, how should they be trimmed up so they can be as healthy as possible and also, more attractive.

Chapter 8 Preparations for the *Acacia koa* review program in Hawaii.

Two days were spent on Oahu getting prepared for the *Acacia koa* review team visit. The biggest part of these preparations involved going out to Maunawilli with Nick Dudley and Tyler Jones and carefully going through a dry run of the presentations to be made at each the five stops that will be made the day that the Koa Research Review Team will be visiting this site. The highlight of this day will be to present 25 years of koa genetic tree improvement and especially the successful development of *Acacia koa* resistant to *Fusarium oxysporum*-caused wilt. The review team will be on Oahu from Feb 15th-17th, 2016.

Subsequently, this same koa review team will be on the Big Island from the 17th until the 20th of February. J.B. Friday and Faith Inman are making most of the arrangements for this part of the trip. On this trip, we traveled to all of the sites that would be visited during the portion of the koa review program and also discussed the messages that we hoped would be shared at each stop.

It should be noted that the purpose of this February koa review week is to show much of the koa research that has taken place previously in Hawaii and also to figure out what additional research needs to get done in order to be able to offer top seed sources and to be able to provide top silvicultural advice to aspiring koa growers. Of course another challenge for this team will be to figure out how to get all this research funded.

The review team will consist mainly of scientists from HARC, IPIF, DOFAW, S&PF R5, NRS, Purdue Univ (TROPHTRIC) and the U of Hawaii. Representatives of these institutions and of some institutions that fund natural resource management projects and some senator's aids have been invited to participate in the debriefing sessions of this meeting.

Figure56 Developing koa that are resistant to *Fusarium oxysporum* wilt (left photo) has been a major objective achieved by HARC during the past decade. Improving genetics for growth characteristics (right photo), and finding better silvicultural practices also holds much promise for improving koa.

Chapter 9 Preparations for the Tom Harrington Review of *Ceratocystis fimbriata* wilt of Ohia

In about 2013, Lisa Keith of ARS, working with J.B. Friday, Flint Hughes, Rob Hauff and others, was able to show, using Koch's Postulates, that a new strain of *C. fimbriata* was the causal agent of a massive amount of death on the Island of Hawaii. However, prior to the discovery that a certain strain of *Ceratocystis fimbriata* is responsible for most of this Rapid Ohia Death (ROD), there was little experience with this particular pathogen in this state. Some emergency measures have subsequently been taken to prevent the movement of infected plants and logs and this may have helped stem the spread somewhat. To date, at least, it appears that this disease has not yet spread to any other island in Hawaii. Also Dr. Keith has continued to do additional studies to learn a more about the etiology of this pathogen. On the Big Island of Hawaii, however, the disease has continued to spread. Between 2012 and 2015 the affected forest area expanded from 3 acres to 35,000 acres. Clearly it might be helpful if some of the world's knowledge about this pathogen, and how to manage it, could be brought to bear on the situation in Hawaii.

Tom Harrington has been working with lethal stains of *Ceratocystis fimbriata* in the tropical forestry situations world-wide for over the past 25 years. In late 2015, Dr. Harrington was invited by DOFAW to come to review the situation, the work that has been done to date, and to get a better feel for the challenge. He agreed and a date was set for the last week of February, 2016.

During this present trip. Two days were spent on the Island of Hawaii with Rob Hauff, J. B. Friday, Flint Hughes and Lisa Keith preparing for the Tom Harrington visit.

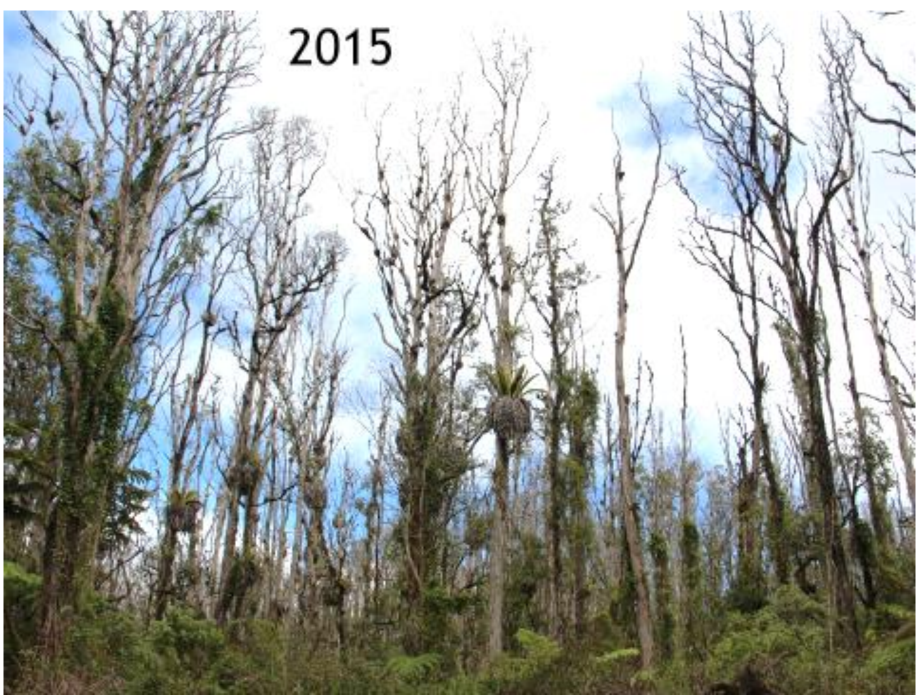

Figure57. An ohia (*Metrosideros polymorpha*) stand that had been growing healthily for hundreds of years suddenly dies. Thirty-five thousand acres of ohia are in this condition on the Island of Hawaii and the disease seems to be spreading rapidly. The cause: a new, exotic, strain of *Ceratocystis fimbriata*.