THE HAWAII HOME OWNER'S GUIDE TO TERMITES

There is a very negative connotation associated with termites because the only time we are aware of them is when they have invaded our homes but termites serve a very useful purpose. No other organism is as efficient at breaking down wood and returning it to the soil. This causes the nutrients that were taken up into this tree during is life to be returned to the soil for use by other plants. Without termites the forests would be piled up with dead trees. They also serve to aerate and increase the moisture in soils. They increase the porosity of the soil and allow entry of other organisms and plant roots. In some areas they provide a source of food for insects, animals and people. All of the termite species in Hawaii were introduced from other areas of the world. Keeping them out of our homes is not difficult when done preventatively but humans always seem to be reactive rather than proactive and so the termite business in Hawaii flourishes.

TERMITES IN GENERAL

Termites are probably the most highly advanced social insect. Evidence of termites dates back to the Cretaceous period about 120 million years ago but there is some research suggesting they are twice as old so they have had a long time to develop. They are of the order Isoptera with twelve families, 282 genera and 2761 species, depending upon who is counting. Fewer than seventy-five species are responsible for most of the damage to structures. They are found throughout the world between forty-five degrees north and south latitude (approximately). They are an insect with six legs and an exoskeleton. They have a head, thorax and abdomen although the thorax and abdomen appear to be joined with no distinct division as in ants or wasps. Most species are white or cream colored. They have a caste system consisting of workers, soldiers, alates and the primary reproductives that founded the colony. The alates or swarmers that fly out of the nest to start new colonies have four wings of equal length. No other insect has this trait.

Termites in Hawaii

In Hawaii, there are four established species. Three belong to the family, Kalotermitidae, which are drywood termites. These three species are the West Indian drywood termite, *Cryptotermes brevis*; the lowland tree termite, *Kalotermes immigrans* and the forest tree termite, *Neotermes connexus*. The fourth species belongs to the family, Rhinotermitidae. This is the Formosan subterranean termite, *Coptotermes formosanus*, also known as the subterranean or ground termite. Since all termites are of the same order, they possess many similarities. All termites have a nest with one or more queens. They each have a caste system with workers, soldiers, primary reproductives, supplementary reproductives, and alates (winged reproductives) which are sent out to start new colonies. The four species in Hawaii vary only slightly in size and color. The West Indian termite adults are sometimes confused with the Formosan termite, the bodies of which are smaller and are dark brown to black rather than amber or honey colored.

The two species discussed in this reading which cause the most damage to property in Hawaii, thus are of most economic importance are the Formosan subterranean termite and the West Indian drywood termite. On rare occasions I have found the Lowland Tree Termite infesting homes but it has always been outside usually in a fence or window frame and in every case the wood has been in poor condition and not maintained. This termite is easy to distinguish as it is so much larger than the West Indian.

The Formosan Subterranean Termite- Family Rhinotermitidae: Genus Coptotermes

I. History

The termite of the most economic importance in the state of Hawaii is the Formosan subterranean termite, *Coptotermes formosanus*, often considered the most aggressive and destructive of all termites. It was officially recorded in Honolulu in 1913 by Swezey but there is evidence that the termite was established at least by 1907 because there are alates in a collection at the Bishop Museum dated in 1907. The collection was made in an area of Honolulu away from the waterfront, so the alates must have come from a colony in the city. Going further back into history, in an old newspaper article published by the Pacific Commercial Advertiser of 31 July, 1869 there was a description of the insect, the swarm, and a damaged fence (Tamashiro, Yates, and Ebesu). Evidently the termite first became established along the waterfront in Honolulu. There it spread throughout Honolulu following utility poles lines and streetcar routes. Some observers believe that swarming termites may have been attracted to the lights of the streetcars where they hitched a ride and were dispersed along the route (Zimmerman, 1948). It is suspected that the termite was brought to the islands from Formosa or China during the era when there was extensive trade between the Kingdom of Hawaii and China. It is likely that it arrived in a potted plant.

Since its introduction to Honolulu during the 19th century the Formosan subterranean termite has spread throughout Oahu virtually anywhere there has been development and currently numbering at epidemic proportions having caused millions of dollars in property damage. The termite has spread to Hawaii (1925), Kauai (1929), Lanai (1932), was introduced into Maui in 1933, eradicated and then reintroduced in the late 1940s or early 1950s. The termite was found on Molokai in 1975. It is found throughout most of Kauai but is restricted to seaports or to areas surrounding seaports on the other islands. The natural spread of this termite after establishment in a new area is slow. Termites are very poor fliers and require human assistance to move more than several hundred feet a year. They have moved between islands in cargo that may include potted plants, lumber, pallets and who knows what.

Recently, at the University of Hawaii a technique called "allozyme electrophoresis" was used to evaluate the genetic similarity of different Formosan subterranean termite colonies on Oahu and Maui. The researchers found that the colonies were virtually identical at this genetic level, suggesting that they might all be descended from a single

"founder colony" introduced to Honolulu in the 1800s. This possibility was also supported by a two-year study of chemicals found on the cuticle (skin) of termites from different colonies (Termite Times July 1993).

II. The Caste System

As with all termites, subterranean termites are social insects with each colony observing a strict caste system. Every effort of each member is directed toward the common welfare and survival of the colony and is among the most sophisticated in the insect world. Each group has its own well-defined duties. They are either building, feeding, defending, or propagating which they carry out for the whole of their lives. Termites have existed for over 180 million years and in that time have developed a social structure and forms of communication we can not comprehend.

The first caste produced and by far the largest in the termite colony are the workers. These individuals have their sexual systems underdeveloped or aborted and their entire existence is guided by an unfailing instinct for continuous labor (Zimmerman 1948). They are creamy white, thin skinned, blind, small and quick-moving. Their description gives rise to the misnomer, "white ants". They perform all the tasks in maintaining the colony. They construct tunnels, excavate chambers, forage for food, feed the king, queen, soldiers, and young, take care of the eggs, maintain the nursery, open and close the flights slits for swarming, and bury or cannibalize abnormal or injured colony members. They are susceptible to drying so they work within tunnels and galleries. The workers can live for four or five years. These are the members of the colony that are responsible for all the damage (Yates and Tamashiro).

The next caste is the soldier. They have a hard, brown, fearsome, armored head with jaws that look like pinchers. These jaws are only for fighting and are so specialized that they cannot be used to chew food, so the soldiers also must be fed by the workers (Yates and Tamashiro). Their major function is to protect the colony from all predators. If a termite tunnel or chamber is breached, an internal alarm is sounded, which calls the soldiers to the break. They will fight any invader that attempts to enter. Most of the predators are ants. Their jaws are able to break an ant in half. When they bite, the soldiers eject a sticky, white latex-like liquid through a pore in the top of their heads. This substance hinders the movement of any enemy. The soldiers will stay in the exposed area until the workers repair the break. During swarming they are found in great numbers when the flight slits are opened to protect against intruders.

The third caste to be produced is the alates or winged swarmers. During a certain time each year a number of eggs for these reproductives are laid by the queen. These are the only sexed termites. The eggs are laid so that they will mature at just the right time for swarming during the warmer humid months of spring usually from April to early July although I have encountered the solitary straggler as late as December. They are dark brown and have a longer flatter body than the worker termites and have four long narrow wings. The alates have compound eyes, whereas the other castes are blind. These are the caste members with which we are all familiar as we observe them

swarming around streetlights or the lights outside and inside our homes. It should be noted that all termites fly and will do so at about the same time of the year and under the same conditions, hot, humid nights with no wind.

The alates take to the air to begin new colonies in the same manner as the drywood termites. Once they shed their wings and find a mate, the pair then finds their physical niche and starts their new colony. In less than a week after the king and queen mate, the first eggs are laid in a batch of about twenty. The eggs hatch in three to four weeks. The young nymphs are fed by the two adults because they are not able to eat undigested food.

These Formosan termites are able to eat cellulose containing products because of three symbiotic protozoa, *Pseudotrichonympha grassi, Holomastigotoides hartmanni*, and *Sperotrichonympha leidyi*, which are found in the alimentary tract of termites and turn the cellulose into simple sugars. They are not born with these protozoa but are inoculated with them in the regurgitated food from their parents. The young are cared for by the king and the queen and they remain in the nursery until they go through two molts. After this, the young are able to forage for themselves. Termites have an incomplete metamorphosis and the young are tine replicas of the adults. They will continue to grow, molt, and develop into either workers or soldiers. The queen will then lay another batch of eggs. This group and all subsequent groups will be fed, cared for, and will acquire the necessary protozoa from the workers and not the queen.

Eventually the queen develops a very distended abdomen which precludes her from being mobile. She becomes little more than an egg laying machine. I collected one that measures about 1 1/8" in length and 1/4" in diameter. All of this addition growth is in the abdomen, her head remaining its original size. This created a bizarre looking creature with her legs unable to touch the ground. If she needs to be moved the workers will move her. She is constantly being cared for by the other termites in the colony and at her peak she is capable of laying an egg per minute. In this way the colony will gradually develop into having several million termites within a period of more than seven years. The king that mated with her originally also grows in size but to a much lesser degree. His role is to continue fertilizing her eggs. The two of them may live for twenty years. If for some reason, the king and queen, or primary reproductives, are removed or are lost by some accident of nature then replacement reproductives will take over the job of procreation.

Once a colony has reached a certain size it is capable of developing satellite colonies with supplementary reproductives. These develop not from the alates but from young workers that develop sexually. They can be identified because they have no eyes as do the alates. The first time I saw this was a retail complex in Waikiki that had been infested through the hollow tile foundation walls. The walls were treated with a mix of chlordane and heptachlor but with in a few months the problems were back. Opening a wall in a store above the foundation we found a supplementary nest that had been able to develop because there was an uninsulated air conditioning pipe inside the wall that condensed enough moisture to sustain the termites. Several years later I found another

one that had build a nest around a P-trap under a kitchen sink. This was one of the drawbacks to using chlordane and heptachlor as we did for so many years. It was effective at killing termites but it repelled them causing them to develop aerial nets in buildings to chasing them to the neighbor's house.

III. Habitat

In order for the Formosan termite to survive there are three basic requirements that must be met. Proper food, adequate moisture, and an environment that provides shelter. The termite's food, which is cellulose, is found in the cell walls of all plants. Most plants and plant product, such as wood, paper, or living plants, can be infested. They seem more inclined to infest some trees more than others. Norfolk Island pine, mango, avocado, citrus, juniper and paperbark are often infested while I have never found them to infest plumeria or monkeypod. Presently, I have several pieces of monkeypod partially buried behind my house in He'eia and termites haven't touched it. Clothing and bolts of cloth, cotton, books, all kinds of paper, even heavily tarred paper, and such materials are damaged severely when accessible. The termite's primary food, however, is wood. The symbiotic protozoa that live inside the termite's body assists in the breaking down of the cellulose so the termite is able to live.

Protein is another important ingredient in the termite diet. One readily available source is the bodies of dead termites. Another is the product of the unique fungus gardens often found in a termite nest. Inside these galleries, combs are constructed of the termite fecal matter (droppings). The relatively high humidity and temperature in these enclosed areas are ideal conditions for fungal spores to develop, providing the essential food supplement.

Moisture is the next essential for survival. The termite does not require an open source of water, although that will help. High humidity will suffice. Moisture can come from normal soil moisture, poor drainage, leaking roofs or plumbing, condensation from air conditioners or pipes. Water should never be allowed to stand on flat roves or decks. The species normally has a subterranean nest, but if a constant source of moisture is available in buildings, even several stories above the ground, no contact with the soil is needed for a nest to be constructed. Nests are not infrequently found on the roofs of concrete buildings. These termites carry damp soil into their extended runways in order to maintain proper humidity. Nests are found at the bases of utility poles, tree stumps, or near some other underground food source. Colonies may be established in boats, ships, water tanks, piers or any similar place where moisture and cellulose are available. The concrete fuel pier at Kaneohe Marine base was infested for many years and the termites would emerge to eat the large planks on the sides or the pier. The structure of this made of "carton." This term has been applied to the friable substance constructed of soil and masticated woody substances cemented together by saliva and excrement of the termites. (Zimmerman, 1948). Unlike the drywood termite the Formosan termite does not expel its fecal pellets but rather utilizes it in the construction of its residence. Therefore, its presence is not detectable by property owners. Extensive damage may have already taken place prior to discovery of a colony.

The third essential for a Formosan termite colony to thrive is proper shelter. The king and queen are unable to set up their home on bare, smooth surfaces. They will need a warm, moist area, such as a buried fence post or the base of an old tree stump. A totally controlled environment is required so they will burrow down and seal the entry point. The nest is expanded with countless tunnels and chambers. The queen's chamber is deep and central within the colony. In times of drought the nest may be developed deeper into the ground to preserve the humidity and temperature. It is thought that the growth of the spores in the fungus gardens also helps to regulate these environmental factors.

As the original food source diminishes, tunnels are built underground in search of new stumps, logs etc. This is the stage of real threat to building, fences and other property. In their quest for food, the termites will build covered "runways" from the ground over foundations and ant-capping and along pipes. Sometimes the runways are even free-standing to reach above ground wood sources. These runways are enclosed to preserve the atmosphere of the nest, shield the termites from light and protect them from natural predators. They are built of a mud-like substance which is in fact the feces of the termites tightly compacted and molded by the workers.

Termites will follow minute cracks and flaws in concrete slabs or piers and it is known that they will penetrate a surprising variety of material in order to reach wood. Once the new wood is located, the colony virtually excavates the whole of the inside leaving only a honeycomb of tunnel walls and the outer layer which preserves the controlled atmosphere. The destruction is devastating and can be remarkably quick. A termite colony is capable of consuming two pounds of wood a day. They can build their mud tubes at the rate of about six inches an hour.

These termites are a formidable pest because of their adaptability. This species, once introduced to Hawaii's tropical climate, has adapted to building nests wherever they find food, moisture and shelter. There has been a dramatic increase in the incidence of aerial colonies of this termite. This is especially true in high rise roofs. Termites get carried to the roof tops of building on the winds. There they pair off and crawl under the roofing material. There is usually wood used to bolt roof-top equipment to and this provides the food. They can live here for several years before entering the penthouse units through openings in the roof.

In 1984 found a nest on the roof of a twenty-story condominium in Makiki and another one on the roof of a building at the Dole Cannery. Neither of these was a supplementary nest and I was able to locate the queens. The alates had flown or been carried there by the wind. They had somehow managed to find each other and get down through the pitch and gravel roof. Once there, they worked their way down through the concrete building following the wiring and plumbing eating any wood they found along the way. A most unusual nest was discovered in the attic crawlspace of a garage in Maunawili. Dozens of corrugate boxes had been taken apart, flattened, and stacked one on top of the other. This contained the perfect place for the alates to crawl into and built a nest.

The house and garage were built from untreated lumber so there was an adequate supply of food. The boxes were stacked in the center of the attic so there was no moisture source nearby despite Maunawili being a very wet area. There was, however, one mud tunnel which led from the nest over to the lowest edge of the roof. It ended there and was saturated from the constant runoff of rain. One could only surmise that the termites used this for their water source as the remainder of the attic was quite dry.

In a house in Kailua I discovered an extensive ground termite infestation that had entered through the slab in several areas. In the master bathroom they entered around the drain for the shower and traveled along the carpet tack strips in the bedroom until they came to the plywood frame of the waterbed. They had done minimal damage to the wood but had eaten through the plastic liner and then through the thick plastic bladder to provide themselves with a secondary source of water. They opened a hole only large enough to allow water to seep out without draining the mattress. My observation here and repeated elsewhere is that termites possess an 'intelligence' that we don't completely comprehend. They knew that by penetrating the bladder of the waterbed they would find a water source that would allow them to establish a secondary nest. Also, they did minimal damage to the plywood frame so it did not collapse under the weight of the water. Again, it has been my observation that termites do not damage structural members of a house to the point of collapse. This would expose them to their predators. I have seen beams split open from termite damage usually but only after the termites have departed.

CONDUCIVE CONDITIONS

HERE WE HAVE A HOUSE WITH A WOODEN EXTERIOR THAT EXTENDS TO THE GROUND AROUND IT ALLOWING TERMITES EASY ACCESS TO THE HOUSE. TERMITES CAN ENTER OVER THE EDGE OF THE SLAB AND BEHIND THE SIDING WITHOUT BEING DETECTED. TO COMPOUND THE SITUATION THE WOODEN FOUR-BY-FOUR FENCE POST IS ANCHORED DOWN IN THE SOIL AND NAILED TO THE HOUSE AND THE DOWNSPOUT KEEPS THE AREA WET. THE VEGETATION IS TOO CLOSE TO THE HOUSE PROHIBITING AN EASY INSPECTION. FORTUNATELY, WHEN I DID THIS INSPECTION THE TERMITES HAD JUST RECENTLY INFESTED THE FENCE POST AND HAD NOT ENTERED THE HOUSE.

SOIL-TO-WOOD CONTACT

THIS POST-AND-BEAM HOUSE, MADE WITH PRESSURE TREATED POSTS, BEAMS AND FLOOR JOISTS, HAD NO SOIL-TO-WOOD CONTACT EXCEPT FOR THIS ONE TWO-BY-FOUR. THE GROUND TERMITES FOUND IT, TRAVELED THROUGH THE REDWOOD TONGUE-AND-GROOVE TO THE UNTREATED WINDOW FRAME WHICH THEY DESTROYED AND UP TO THE ATTIC AND SEVERELY DAMAGED ABOUT A DOZEN RAFTERS THAT WERE ALSO UNTREATED.

FORM BOARDS LEFT IN PLACE AND IN CONTACT WITH THE SOIL

WHEN A CONCRETE FOUNDATION OR SLAB IS POURED WOODEN FORM BOARDS ARE USED TO CONTAIN IT. TOO OFTEN THEY ARE LEFT IN PLACE AND GROUND TERMITES FIND THEM. ONCE THEY ARE CONSUMED THE TERMITES MOVE ON TO THE REST OF THE HOUSE.

PLANTS TOO CLOSE TO THE HOUSE

THIS TREE AND THE PLANTS GREW TOO CLOSE TO THE HOUSE AND TERMITES USED IT AS A BRIDGE INTO THE STRUCTURE. THEY DID NOT INFEST THE TREE BUT BUILT TUBES OVER ITS BASE AND ENTERED THE DOUBLE WALL ESCAPING NOTICE. NOTE THAT THE BEAM PROTRUDING FROM THE SIDE OF THE HOUSE AT THE TOP OF THE TREE IS COMPLETELY HOLLOW AND SPLIT OPEN.

CONCRETE POURED AROUND A WOOD POST

THIS POST THAT SUPPORTS A LANAI ROOF WAS SITTING ON A CONCRETE SLAB. ANOTHER SLAB WAS POURED AROUND IT AND GROUND TERMITES ENTERED THROUGH A SMALL CRACK VISIBLE AT THE LEFT AND INFESTED THE POST. THE HOMEOWNER WAS COMPLETELY UNAWARE OF THE EXTENSIVE DAMAGE THAT EXTENDED INTO THE ROOF SINCE THE TERMITES STAYED IN THE CENTER OF THE POST AND DID NOT EXPOSE THEMSELVES.

GOOD CONSTRUCTION FOR A POST AND BEAM STRUCTURE

THIS IS THE PROPER WAY TO SUPPORT A WOOD POST. THERE IS A TERMITE SHIELD UNDER THE POST, A 'TOFU' BLOCK UNDER THE SHIELD AND A CONCRETE FOUNDATION THAT SITS AT LEAST EIGHT INCHES ABOVE GRADE. THE POST IS PRESSURE TREATED LUMBER. ALL THIS MAKES THIS POST IMPREGNABLE TO TERMITES.

IV Predators

Termites have many predators. Perhaps the most dangerous enemies to non-swarming termites in Hawaii are ants, several species of which attack termites whenever there is an opportunity. *Pheidole megacephala* is particularly likely to inflict heavy casualties. However, under normal circumstances the termites are well protected from attacks by ants. It is usually only when some accident befalls a colony that it is exposed to attack by ants in Hawaii. Ground termite colonies that are well established often have too many individuals to be adversely affected even by constant predation by ants. At the time of swarming reproductives are most vulnerable to attack. If swarming takes place in daylight (as it does occasionally, although it normally takes place at night), dragon-flies, skinks, mynah birds bulbuls and sparrows gorge themselves on the flying termites. At night geckoes and the cane toads, Bufo marinus toads take over the slaughter. Geckoes are particularly helpful in reducing the numbers which might enter houses by taking up their hunting stations on windows, screens and ceilings and capturing with insatiable appetites the swarming termites which are attracted to lights. The singe native Hawaiian bat is rare and local in habit and is not regularly attracted to the lowlands where termites are abundant. Pemberton (1928:147) found a lepismatid, a type of silverfish, living in the nests and galleries of certain termites in Borneo and feeding upon the termite eggs and nymphs. A single attempt to introduce the species into Hawaii did not succeed because of the death of the small colony before the specimens could be released. There have been no really effective methods of biological control of termites found. There was some work done with nematodes on the Mainland but did not prove to be effective and to the best of my knowledge was never tried here. The small Hawaiian snake, *Ramphotyphlopsw braminus*, is capable of eating large quantities of termites and is small enough to enter the ground termite nests. For those not familiar with it the snake is usually four to six inches and is a shiny dark gray, almost black. They are quite thin and at first glance some people think they are an earthworm. They have no eyes but can be recognized as a snake by the tongue that constantly flits out to detect prey or predators. Interestingly, the species is parthenogenic, all females and they can reproduce without being fertilized by a male which helps insure their survival.

V Geographical Distribution

Termites are exceedingly abundant, they are found throughout the tropical and sub-tropical areas of the world, and in some areas extending into the temperate regions. Two species, *Reticulitermes lucifugus* and *Kalotermes flavicollis*, are found in Europe but they do not appear to thrive farther north than Paris in France, except that a third species, *Reticulitermes flavipes*, a few colonies of an introduced termite, still maintain themselves in the basements of warehouses in Hamburg. Another species, *Zootermopsis angusticollis*, is found extensively on the Pacific coast of Canada. The nearer to the equator one travels so the number of species and the total number of termites increase, so that in very large areas of the world cellulosic materials (all material of vegetable origin) are being constantly destroyed by termites (Hickin, 1971). Millions of tons of wood are utilized annually world-wide. The developed countries use far more wood than underdeveloped countries. Since a substantial proportion of the

people in developed countries enjoy a higher standard of living with the majority of residences and various buildings constructed of lumber, a higher magnitude of problems occur with termites. The following countries are just some of the many that are battling termite infestation: Australia, Bahamas (Nassau), Barbados, Hong Kong, Kenya (Nairobi), Malaysia (Kuala Lumpur and throughout West Malaysia), New Zealand, Philippines (Manila), Singapore, Trinidad (Port of Spain) and the United States. Elaborate as to which states.

Throughout the Pacific Rim there are countries and islands that have been infested with the Formosan subterranean termite. Pan American World Airlines used Midway as a refueling point from 1935 through 1947 on its Trans-Pacific route from San Francisco to Honolulu, Midway, Wake, Guam and Manila. Part of Pan Am's beautification program was the introduction of 100 tons of soil from Guam in 1935. Although the soil was certified to be free of "parasites, animals or vegetables," it was undoubtedly the start of the Formosan Subterranean termite on Midway. Termite infestations have spread to most of the structures on both islands. The battle of Midway June 4-6, 1942, severely damaged and destroyed most of the above ground facilities. However, following this battle and through 1945, the facilities greatly increased and new construction started. (Beal, 1985) In 1957, a $40,000,000 building program was started on Midway with little or no preventive termite treatments. This, of course, led to a large build-up of termite problems. As early as 1970, extremely large flights of alates were disrupting outdoor lighted recreation events on warm May and June evenings. Infestations of *Coptotermes formosanus* could be found in most wooden structures during the 1960's and 1970's, and when high winds broke off or blew over ironwood trees, evidence of *C. formosanus* could be found in the center of the trees. Many trees in the housing area are under attack as is evidenced by the mud tubing coming to the surface of scars on the trees. In May 1984, Navy personnel conducted a thorough inspection of approximately 50 usable buildings on Sand Island. *C. formosanus* was found infesting 85 percent of the buildings in varying degrees. Some infestations are so severe that major structural repair may be required (Beal, 1985).

Because of its relatively warm climate, the south-western part of Japan is a suitable habitat of the Formosan subterranean termite. The oldest reliable record, dated 300 years ago, state that is termite was called "Do-toos" (temple or shrine destroyer) due to its enormous destructivity. Before World War II, the Formosan subterranean termite was found in only 2 areas of Japan; one facing the Pacific (Shizouka Pref.), the other on the Sea of Japan (Yamaguchi Pref.). The status of the latter has not changed since the war; however, several new Pacific outbreaks associated with U.S. military bases in Kanagawa have occurred. These sudden and sporadic introductions were probably all started by humans who unknowingly transported lumber containing live termites. This is conceivable since the present law only requires logs imported into Japan be fumigated with methyl bromide, while cut lumber may be brought in without fumigation. Beside Kanagawa Prefecture, the Formosan subterranean termite also appeared after the war in Chichijima in the Bonin Islands, where it is presently thriving and has spread to nearby Hahajima (Mori, 1985).

Termite damage in Japan is severe because many building are made of wood. However, when compare with the Japanese termite*, Reticulitermes speratus* (Kolbe); the number of cases caused by the Formosan subterranean termite is rather few. No nation-wide data are available, but according to a survey conducted by our agency between 1971-73, about 94% of the incidents of termite infestation were cause by the Japanese termite and only 5.8% were by the Formosan subterranean termite. This may be due to the fact that most of the buildings surveyed were located inland distant from the coast. In terms of damage severity, however, the Formosan subterranean termite is a far more serious pest and lives up to its ancient reputation. That is, there are many buildings which have been destroyed by the Formosan subterranean termite, but none destroyed by R. Speratus (Mori, 1985).

Species of the genus Coptotermes are widely distributed in China; with a northern boundary line in Jianhu County, Jiangsu Province (N.33 0 44'), the southern in Shanhu Island, Xisha Islands, Guangdong Province, the eastern in Taiwan Province, and the western in the Cichuan Basin. Although several Coptotermes species are known in China, most infestations are attributed to *C. formosanus*. Populations of *C. formosanus* colonies are so large that serious damage results from attacks on goods in storage, railroad cars, boats, ships, buried communication cables, crops, and forest trees, etc. Species of the genera Odontotermes and Macrotermes are the main pests attacking earth dams of reservoirs, but *C. formosanus* also occasionally builds nests in earth dams. The cavities and galleries formed within a dam may result in its failure (Gao, 1985).

Although the identified termite species in China has been increased from 17 to 201 between 1935 and 1983, among them Coptotermes has always been the most severe pest to human economic activities. According to a survey of 23 cities in China, the infested area has reached 22,200,000 m2, causing a loss of about 0.33 billion Chinese Yuan. In addition, many famous wooden monuments and relics are attacked by Coptotermes to some extent. Furniture, clothes, sleepers, boats, landscape gardens, cables, rubber, agricultural crops as well as metal products also suffer attacks from Coptotermes. The Chinese government has considered termite damage a serious problem. In addition to the southern provinces of the Yangtze River, the main regions with termite distribution, termite control units have been formed in the larger cities of the northern China such a Beijing, Tianjin, Dalian, and Qingdao. Provincial termite control societies have also been formed in Guangdong, Anhui, and Zhejiang provinces in the south. Termite control research stations have become common at a county level in some provinces. In 1983, the National Cooperation Center for Termite Control and Research was formed. The first issue of "Science and Technology of Termites" edited by the center was published in 1984. There are four termite research groups belonging to the Center which organize the cooperation research and solve the problems of common interest with 18 research institutes of the cities. In general, the progress of the termite control and research program has paralleled the economic development of China (Lin, 1985).

Some of our country's southern states in the Gulf of Mexico region have reported termite infestations. In 1980, a well-established colony of the Formosan subterranean termite, *Coptotermes formosanus* was confirmed in a condominium in Hallandale, Florida. Following this discovery, 7 nearby condominiums and 1 house were also found infested. During 1982-83 survey, C.R. Thompson used light and sticky traps to collect alates of *C. formosanus*. Swarmers were taken over an area bordering 155 km2 in Broward and Dade counties. In 1984, two remote infestations surfaced in Orange and Escambia counties of Florida. A large swarm was reported from the Escambia infestation in May 1985; however, the active infestation could not be located by stake survey. The newest citing in April 1985 occurred on a wooden boat docked in Palm Beach County. This infestation was located ca.100 km north of Port Everglades, the northeast boundary of the C. formosanus survey conducted by C.R. Thompson. Because no land infestation had been reported in the West Palm Beach area, this incident implies a maritime mode of introduction for C. Formosanus (Su and Scheffrahan, 1985).

The Formosan subterranean termite, Coptotermes formosanus, was first discovered in Louisiana by pest-control operators in the spring of 1966. Two widely separated but apparently well-established infestations were found in Lake Charles and New Orleans suggesting that two independent introductions had occurred several years earlier. Because these infestations had become locally widespread and were found near or on military installations, I speculate that C. formosanus may have entered Louisiana near the end of the Second World War on military transport ships returning from the Orient. Although additional infestations have been reported in the state, none has become as serious as the original ones (Fage, 1985).

Other then when wood is used to satisfy human needs, termites, together with other wood-destroying organisms play a wholly beneficial role. They then function as scavengers, boring into, breaking up, and digesting woody tissue. The products of their activity are available, either directly or indirectly through the activities of other organisms as a contribution towards the nutritional requirements of a succeeding generation of trees.

If we examine the total bio-system of tropical and sub-tropical areas, the number of termites present is of the greatest magnitude and their activity and effect are likewise immense. This great importance of the termites in the bio-deterioration of woody tissue in the areas of the world where they abound is not always apparent to the untrained observer, due to their light-avoiding behavior, except in the brief period of their nuptial flight (Hickin, 1971).

CONTROL OF GROUND TERMITES

The first step in controlling ground termites is physical barriers.

All soil-to-wood contact needs to be eliminated. Insure that a space of four to six inches separates any wood on the house and the soil. Remove any scrap wood under the house. Don't allow siding of any kind extend below the soil.

Drain downspouts away from the house and correct any slopes in the yard that direct water to or under the house. Cap off all sprinklers adjacent to the house.

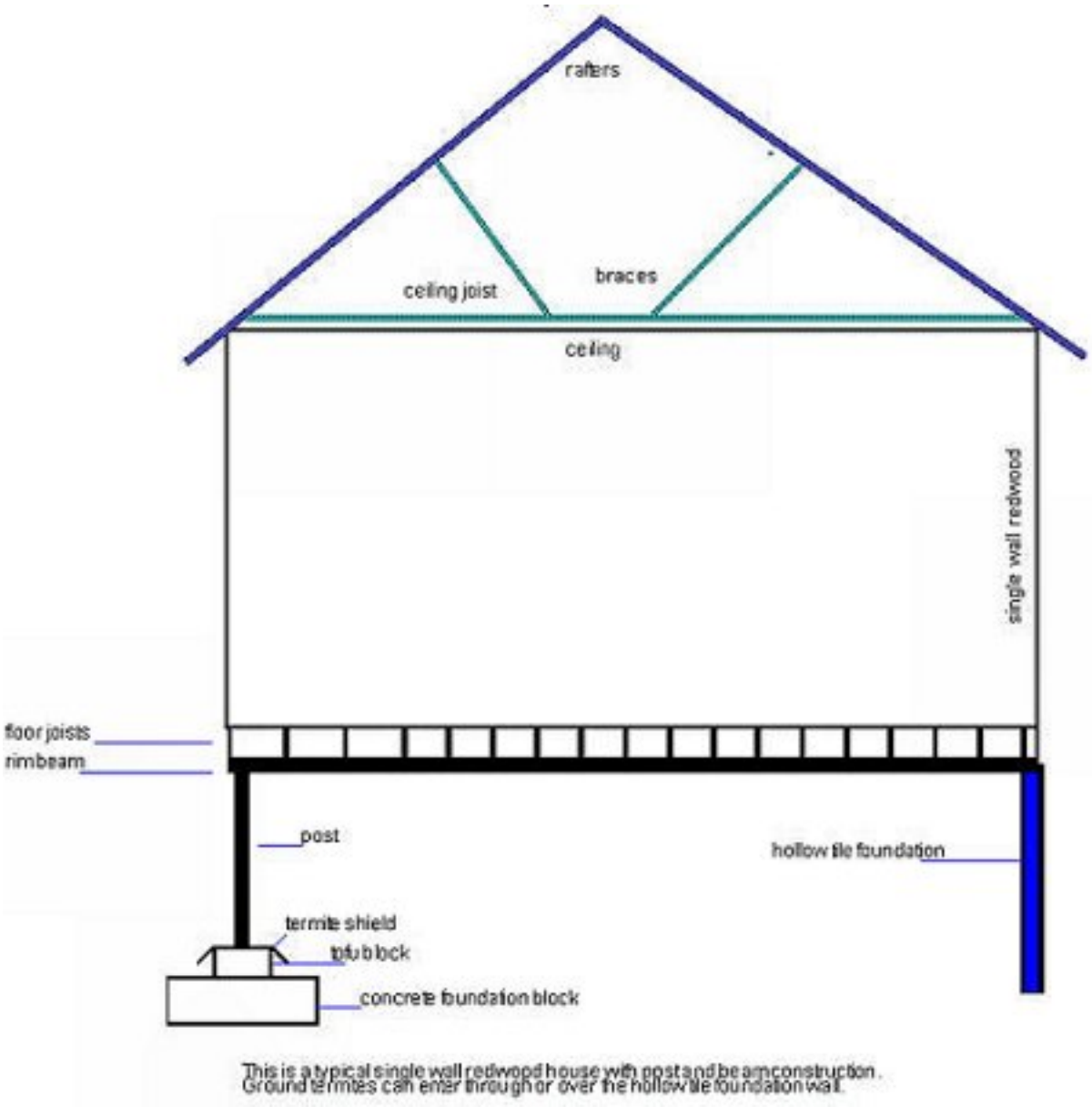
Don't plant anything within eighteen inches of the house. Norfolk Island pines are not a good residential tree because once infested they become weak around the base and can fall with destructive force.

SENTRICON

Traditionally, in the effort to keep ground termites out of a structure, a combination of physical barriers, (termite shields, Basaltic Termite Barrier, Termimesh, etc.) and termiticides were the only choices available. These were strictly defensive measures in that they hindered the access of ground termites into a structure. In 1994 this changed when Dow-AgroSciences introduced the SENTRICON termite baiting system. Briefly this works by placing bait stations with wood in them in the ground around a structure. When ground termites find one or more stations the wood is replaced with sawdust impregnated with a chitin synthesis inhibitor, hexaflumuron. The worker termites feed on this and in turn feed it to the rest of the colony. This is not a toxicant but an insect growth regulator which prevents young termites from molting their skin and consequently becoming adult worker termites. The number of adult workers declines due to natural attrition and there are no replacements. Consequently, the colony dies or its numbers are reduced to the point that it is no longer a threat to nearby structures. For the first time ever the termite companies now have an offensive weapon. This has been shown to be a very effective way to control ground termites and should be a serious consideration for every homeowner particularly those whose homes have had ground termite infestations in the past.

TERMIDOR

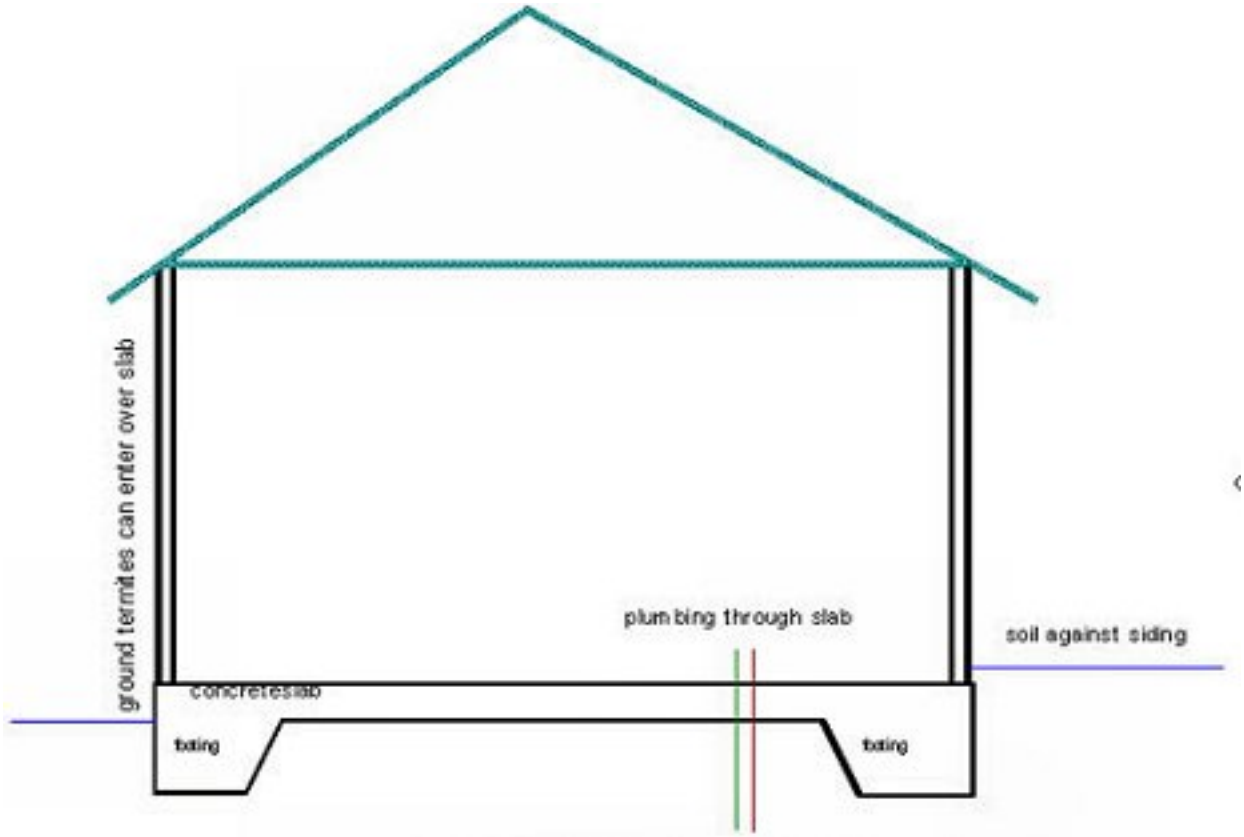
Termidor is a liquid insecticide that is applied to the soil around and under a structure. It utilizes a unique action known as the "Transfer Effect™" to effectively control termite colonies. Termidor does not repel termites - termites can't smell, see or feel the insecticide, so they crawl freely through treated areas. When a termite eats or even comes in contact with the insecticide, it unknowingly transfers Termidor back to the colony on its body. Every termite it contacts will transfer Termidor's active ingredient, fipronil, to other termites.



POST AND BEAM CONSTRUCTION, PROPERTY DONE AS SHOWN IN THE DIAGRAM ABOVE, GENERALLY OFFERS GOOD PROTECTION AGAINST GROUND TERMITE INFESTATION. ONLY RARELY WILL THE GROUND TERMITES BUILD THEIR MUD TUBES OVER THE FOUNDATION AND METAL TERMITE SHIELD.

THIS PHOTO SHOWS AN EXCEPTION. ALL OF THE DIRT VISIBLE IN THE PHOTO IS A MASSIVE TERMITE TUBE THAT LEADS UP TO THE POST SUPPORTING THE HOUSE. FROM THIS ENTRY POINT THEY INFESTED AND SEVERELY DAMAGED ALMOST THE ENTIRE STRUCTURE INCLUDING THE FLOORS AND WALLS. THE HOUSE HAD TO BE RAZED AS IT WAS NOT SALVAGEABLE.

HOLLOW TILE FOUNDATIONS ARE PROBABLY THE MOST VULNERABLE ESPECIALLY RETAINING WALLS. THIS PHOTO DEMONSTRATES THIS. AT ONE TIME THIS WAS A COVERED LANAI WITH A LOW HOLLOW TILE WALL. WOOD FRAMING WAS ADDED TO THE TOP OF THE WALL AND THE EXTERIOR COVERED WITH SIDING AND THE INTERIOR WITH SHEETROCK. GROUND TERMITES ENTERED THROUGH THE HOLLOW TILE BEHIND THE SHEETROCK AND SEVERELY DAMAGED THE FRAMING INSIDE THE WALL. THEY HAD BEEN IN HERE FOR MONTHS OR EVEN YEARS WITHOUT A TRACE UNTIL THE CARPET WAS PULLED BACK. THE SHEETROCK WAS PARTIALLY REMOVED AND THE MASSIVE TERMITE TUBE SCRAPED OFF BUT IN A MATTER OF HOURS THEY HAD CONSTRUCTED THIS TUBE LEADING BACK TO THEIR FOOD SOURCE.



Typical concrete slab-on grade house with double wall construction.
Ground termites can enter around the plumbing, over the edge of the slab or where soil has accumulated against the wood siding.
Due to the weight of the footings they will settle causing cracks in the top of the slab but rarely do they extend through the four inch thickness of the concrete.

MANY OF THE HOMES BUILT SINCE THE 1950'S HAVE A CONCRETE SLAB-ON GRADE FOUNDATION. THESE ARE MUCH MORE VULNERABLE TO GROUND TERMITE INFESTATION AS THERE IS LITTLE IN THE WAY OF A PHYSICAL BARRIER TO KEEP TERMITES OUT. THIS TYPE OF CONSTRUCTION WAS MADE POSSIBLE BY CHLORINATED HYDROCARBON INSECTICIDES SUCH AS ALDRIN, DIELDRIN AND CHLORDANE THAT WERE DEVELOPED DURING WORLD WAR II. THESE WERE TOXIC AND PERSISTENT COMPOUNDS THAT COULD BE APPLIED PRIOR TO POURING THE CONCRETE THEN REAPPLIED ABOUT EVERY FIVE YEARS. THE WEAK SPOT IS THE PERIMETER OF THE HOUSE WHERE NEW SOIL EVENTUALLY ACCUMULATES AGAINST THE SIDING OR SHRUBS ARE PLANTED AND THAT BREAKS THE INSECTICIDE BARRIER. FREQUENTLY ADDITIONS ARE MADE TO THE HOUSE AND THE INSECTICIDE BARRIER IS BROKEN AND NO NEW INSECTICIDE APPLIED.

TREE STUMP AND CUT LOG

THIS PHOTO WAS TAKEN IN THE PARK ON WA'AHILA RIDGE. GROUND TERMITES ARE FOND OF NORFOLK ISLAND PINES AND THEY INFEST THE CENTERS BUT DO NOT BREAK THROUGH THE BARK. IN THIS CASE THEY ATE RIGHT UP TO THE OUTER RIM OF THE TREE. THE TREE WAS WEAKENED CONSIDERABLY SO THAT WHEN A STRONG WIND CAME ALONG IT FELL OVER. NOTE THAT IN THE PHOTO OF THE CUT LOG THAT WAS SEVERAL FEET UP FROM THE STUMP, THE TERMITES DID NOT EAT THE PARTS OF THE TREE BRANCHES WHERE THEY TRAVEL HORIZONTALLY THROUGH THE TRUNK OF THE TREE AND JOIN THE CENTER SECTION. THIS IS NOT AN UNCOMMON OCCURRENCE AND THEY HAVE FALLEN INTO HOUSES AND CARS. THIS IS NOT A GOOD TREE TO PLANT IN YOUR YARD.

THE DANGER IN HAVING AN INFESTED TREE IN YOUR YARD IT THAT GROUND TERMITES CAN TRAVEL THROUGH THE ROOTS. IF THE ROOTS GO UNDER THE FOUNDATION OF THE HOUSE IT IS A SUBWAY THAT CAN LEAD THEM IN. BECAUSE THEY ARE INSIDE THE ROOT AND AFFORDED ITS PROTECTION THEY CAN BE VERY DIFFICULT TO CONTROL.

AERIAL NEST OF GROUND TERMITES

THIS PHOTO WAS TAKEN OF AN AERIAL NEST OF GROUND TERMITES ON A HIGH-RISE BUILDING IN HONOLULU. THEY HAD A LARGE NEST UNDER THE ROOFING MATERIAL AND HAD TRAVELED DOWN EIGHT FLOORS EATING UP EIGHT SUCCESSIVE BATHROOMS AS THEY WENT.

GROUND TERMITE FLIGHT SLITS

TERMITES ARE SOCIAL INSECTS AND ALL THE TERMITES IN ONE COLONY ARE BROTHERS AND SISTERS HAVING BEEN BORN FROM ONE MOTHER. TO START NEW COLONIES THEY MUST LEAVE THE NEST AND FIND A PARTNER. THIS IS DONE EVERY SPRING AS DESCRIBED EARLIER. TO FACILITATE THE SWARMERS GETTING OUT OF THE NEST THE WORKERS WILL CREATE FLIGHT SLITS IN THE WOOD THEN FILL THE SLITS WITH MUD UNTIL THE MOMENT THE SWARMERS ARE READY. THEN THEY OPEN THE SLITS AND STICK THEIR NOSES OUT. IF THERE IS NO WIND THEY LAUNCH BY THE THOUSANDS. IF IT IS WINDY THEY CLOSE THE SLITS UP AND WAIT FOR BETTER CONDITIONS. IF THE TERMITES ARE INSIDE A WALL THEY WILL EAT THROUGH THE SHEETROCK OR OTHER MATERIAL TO ALLOW THE SWARMERS TO ESCAPE. GENERALLY, THE FLIGHT SLITS ARE SEVERAL FEET HIGH TO AID THE SWARMERS IN BECOMING AIRBORNE. THEY ARE POOR FLYERS AND WITH WINGS MORE THAN TWICE THE SIZE OF THEIR BODIES IT IS BETTER DESCRIBED AS FLUTTERING. I WATCHED THEM SWARM FROM A BAMBOO STUMP THAT BARELY PROTRUDED FROM THE GROUND AND IT WAS SURROUNDED BY DOZENS OF TOADS OF ALL SIZES THAT PRACTICALLY INHALED THE TERMITES AS THEY EMERGED.

HOLLOW TILE RETAINING WALLS

HOUSES BUILT ON HILLSIDES WITH RETAINING WALLS HAVE ALWAYS BEEN A PROBLEM FOR SEVERAL REASONS. MORE OFTEN THAN NOT, THE SOIL THAT WAS BACK-FILLED AGAINST THE WALL WAS NOT TREATED WITH LIQUID INSECTICIDE. ONCE THE WALL WAS IN PLACE IT WAS DIFFICULT OR IMPOSSIBLE TO TREAT THE SOIL AND STOP THE TERMITES ONCE THEY INFESTED. GROUND TERMITES ARE ABLE TO DISSOLVE THE LIME MORTAR USED TO HOLD THE TILE TOGETHER SO THEY CAN COME RIGHT THROUGH THE WALL. VERY OFTEN THESE WALLS ARE IN A PLACE THAT IS NOT EASY TO GET TO OR MAY BE COVERED WITH SHEETROCK SO THERE IS NO EASY WAY TO INSPECT THEM.

TERMITES ENTERING OVER THE EDGE OF THE SLAB

THIS IS ONE OF THE MOST FREQUENT WAYS TERMITES ENTER A HOUSE WITH THIS TYPE OF CONSTRUCTION. THEY ARE MUCH MORE INCLINED TO ENTER THIS WAY IF THE SIDING IS CLOSER TO THE SOIL BUT IF THEY WANT TO COME IN THEY WILL.

TERMITES ENTERING AROUND THE PLUMBING

WHERE PIPES AND DRAINS PENETRATE THE CONCRETE SLAB GROUND TERMITES WILL ENTER AS WELL. OFTEN THERE IS A LEAK AND THAT PRECIPITATES THE INFESTATION. THIS HOUSE HAD TWO BATHROOMS SIDE-BY-SIDE AND TERMITES ENTERED THROUGH THE DRAIN IN ONE BATHROOM AND SPREAD TO THE ADJOINING ONE DOING CONSIDERABLE DAMAGE.

FREE-STANDING TUBE

THIS PHOTO WAS TAKEN UNDER THE POOL OF A PENTHOUSE CONDOMINIUM. GROUND TERMITES HAD ESTABLISHED AN AERIAL NEST ON THE POOL DECK AND WERE WORKING THEIR WAY DOWN LOOKING FOR MORE FOOD. THIS TUBE WAS APPROXIMATELY TWO AND A HALF FEET LONG AND WAS SUSPENDED FROM THE POOL DECK ABOVE. WHEN I DISCOVERED IT THERE WERE STILL TERMITES INSIDE OF IT BUILDING THEIR WAY DOWN. I HAVE FOUND SIMILAR TUBES BEING BUILT FROM THE GROUND UP UNDER HOUSES IN THEIR PURSUIT OF ADDITIONAL FOOD SOURCES.

GROUND TERMITES ENTER THROUGH A BROKEN TOILET DRAIN PIPE

ON THREE OCCASIONS I HAVE FOUND GROUND TERMITES ENTERING HOUSES, OR IN THIS CASE A HOTEL, THROUGH THE TOILET DRAIN PIPE. THE PIPE HAS BROKEN SOMEWHERE UNDERGROUND AND TERMITES ENTERED IT PROBABLY FOR THE MOISTURE IT PROVIDED. THEY THEN BUILT A MUD TUBE INSIDE THE PIPE TO WHERE THE TOILET IS ANCHORED TO THE FLOOR. THEY THEN DISSOLVE THE WAX SEAL BETWEEN THE TOILET AND THE FLOOR AND TRAVEL UNDER THE FLOOR COVERING, USUALLY LINOLEUM, TO REACH FRAMING LUMBER OR CABINETS. THIS METHOD OF INFESTING THE HOUSE IS DIFFICULT TO DETECT AND CAN ONLY BE REMEDIED BY REPAIRING THE BROKEN DRAIN WHICH MAY INVOLVE BREAKING THE CONCRETE SLAB.

The Economic Significance--Crops and Forestry

Termites do not confine their attention to dead plant tissues such as wood. In many parts of the world, species of termites are serious pests of growing crops including living trees. It is thought that termites are seldom primary pests, only damaging the plant, shrub or tree when it has already been affected by fire, a fungus or an insect of another order. For instance, once another insect has bored into a stock of a vine, the termite reproductives will enter fight holes of that insect and start a colony which results in the stock finally splitting. The fact that termites usually appear to be secondary pests does not make them of less importance. The initial defect affecting the plant is often of minor importance, but after allowing ingress to termites the effect may be the complete destruction of the plant or, at least, a reduction in its value as a crop (Hickin, 1971) Cultivated plants in those areas of the world where termites occur can be divided into four groups: plantation crops--generally, these are woody perennials; field crops--generally, these are herbaceous annuals; young trees--in nurseries and plantations; older trees--mainly in forests, but including amenity trees.

The cacao plantation crop has been reportedly under attacked by termites in the Gulf of Guinea, Ghana, the Ivory Coast, Nigeria, New Guinea, Samoa, New Britain, and West Africa. In Zanzibar, termites have attacked the planted seedlings on clove plantations. Coconut palms seedlings have been attacked by subterranean termites, while the mature palms have been attacked by drywood termites. Nigeria, Malaysia, Indonesia, India, Ceylon, and many coastal strips of tropical countries have been affected. Coffee crops in the Congo, India, Uganda, Brazil, and Surinam have reportedly been under attack by termites. Arabia and Sudan have found termites in their date palm crops. Africa, Malaysia, and Indonesia report termites in their oil palm crops. Rubber trees in Malaysia, Indonesia, Vietnam, Ceylon, Brazil, Guyana, Nigeria, and southern Texas report termite infestation. Sugar cane has been under attack by termites in many tropical and sub-tropical countries including but not exclusively found in Panama, Jamaica, Leeward Islands, Venezuela, Cuba, Puerto Rico, Barbados, Guyana, Guadeloupe, Kenya, Somalia, Mauritius, India, Pakistan, Formosa, South China, Hawaii, and Australia. Tea bushes have been reported under attack in China, Formosa, India, Ceylon and Malaysia.

Field crops that have been infested with termites are cotton and groundnuts. The cotton plant in Sudan, East and Central Africa, and Arabia all report termite activity. Surprisingly enough, the states that produce cotton in the United States have not been affected. In Sudan, Senegal, and East Africa termites have damaged groundnuts crops.

Pasture crops that are infested with termites are rice, wheat and maize. Japan, Formosa, and Nigeria report heavy infestation in their rice crops. Northern India and upland northern Tanzania report damage in their wheat crops. Southern Tanzania has reported activity in their maize crops.

Young trees in nurseries and plantations in the tropical and sub-tropical regions of the world where the rainfall is low and conditions are of drought or near drought, termite attack is most acute. A popular tree species for the termite is the eucalyptus. Several townhouse developments have included eucalyptus in their landscaping only tom have them become infested and in turn become the source of infestations going into the buildings. Young trees in forests and plantations are hard hit in tropical Africa, South America, China, Ceylon, and India.

Termites are found in generally dry areas rather than in wet areas in older trees. Damage to older trees in a natural forest is generally slight in comparison to isolated ornamental trees. Older eucalyptus trees are heavily attacked in tropical Africa and east Australia. In Java, older teak trees are infested. From half to three-quarters of the teak in the age group twenty to thirty years is under constant attack which causes damage of economic significance (Hickin, 1971).

The plants and trees that have been attacked by termites in Hawaii are papaya, sweet corn, mango, avocado, various citrus, Norfolk pine, and eucalyptus. Judging from the number of homes on the Ewa plane that were infested shortly after construction it is reasonable to assume they were infesting the sugar cane that had been grown there previously.

TREE KILLED BY GROUND TERMITES

THIS AVOCADO TREE IN HAWAII KAI WAS COMPLETELY INFESTED WITH GROUND TERMITES UP AS HIGH AS I COULD REACH AND IT WAS DEAD. THE OWNER OF THE HOUSE SAID THE PREVIOUS YEAR IT SHOWED SOME SIGN OF INFESTATION BUT WAS STILL BORE FRUIT THEN DROPPED ITS LEAVES AND EXPIRED.

The West Indian Drywood Termite- Genus Cryptotermes

I. History

The West Indian drywood termite is of significant economic importance. It is a species that is responsible for considerable property damage in Hawaii. Its origin is unknown. Considering that the earliest ships arriving in Hawaii were made of wood, as were their cargo crates and barrels, its introduction has probably been repeated numerous times. This drywood termite was first reported in Hawaii in the 1860's. It is scattered over much of the southern continental US, the Pacific Rim, and in the Caribbean where it is a serious pest, especially in Puerto Rico. It is distributed throughout the Hawaiian Islands. This termite is much more transportable than the ground termite but its damage is considerably less. This is due to the fact that it reproduces much slower and has significantly smaller colonies. Its presence should not be ignored as it is capable of serious damage if left unchecked.

DRYWOOD TERMITE DROPPINGS

THE COLOR OF THE DROPPINGS FROM DRYWOOD TERMITES IS DEPENDENT NOT ONLY ON THE TYPE OF WOOD THEY ARE EATING BUT THE PART OF THE WOOD AND, I BELIEVE, THE INDIVIDUAL TERMITE. HERE WE SEE TWO DISTINCTLY DIFFERENT COLORS OF TERMITE DROPPINGS COMING FROM THE BOTTOM OF THE SAME FOUR-BY-FOUR POST. THIS WAS AN ACTIVE INFESTATION IN AN OLDER HOUSE IN MANOA. THE COLOR OF THE DROPPING HAS NOTHING TO DO WITH THE AGE AS IS COMMONLY BELIEVED. TERMITES INFESTING OAK FLOORS AND FURNITURE EXCRETE DROPPINGS THE SAME COLOR AS THE OAK.

DRYWOOD TERMITES WERE INFESTING SEVERAL CEILING BEAMS IN A TOWNHOUSE. THE BEAMS WERE ABOUT TWO FEET ABOVE THIS SHELF AND THE DROPPINGS BOUNCED AS THEY HIT. AGAIN, NOTE THE VARIATION IN COLOR.

II. Caste System

The West Indian drywood termite is not a true social insect, as it does not have distinct caste members to perform specific functions within the colony. Its system consists of a royal couple, a king and a queen, usually the founders of the colony. There are also soldiers and nymphs. There is no true worker class. The nymphs serve as workers until they develop into alates (winged reproductives) when they will swarm in search of establishing a new colony. Supplementary queens may also develop. The function of the royal pair is procreation. Once the bridal chamber is constructed, mating will take place. During the first three months the queen lays only two to four eggs. These take approximately two months to hatch. The eggs are pink and shaped like jelly beans. These take approximately two months to hatch. The nymphs have to be fed predigested food from the adults as they are not born with the protozoa (primitive unicellular animals) necessary to digest cellulose. Protozoa secrete cellulose which breaks down the cellulose into simpler materials capable of being digested by the termites. Such a relationship, where two dissimilar organisms are intimately associated together for their mutual benefit, is known as symbiosis. Protozoa which are utilized by the West Indian termite are *Foaina humilis* Kirby (1942), *Devescovina striata Foa* (1905), *Tricercomitus divergens* Kirby (1930), *Hexamastix conclaviger* Kirby (1930), Calonympha sp. (probably *C. grassi Foa*, (1905) (Zimmerman, 1948). The king and queen will rear only the first group of nymphs until they can feed themselves. Subsequent eggs and young will be cared for by the older nymphs. During the first year the queen will lay eggs only for the first three months then waits several months before laying again. In time, the

queen develops a distended abdomen to facilitate her egg-laying. The king is there to fertilize her when necessary. The development of the West Indian colony is very slow. After about a year, the colony contains only about a dozen termites.

Other than the royal couple, the soldiers are the only members in the system that have a specific function. Soldiers are produced after the first year. Their task is to protect the colony from invaders, which in most cases are ants. They are totally dependent on the nymphs for their food, as they are unable to chew food and feed themselves.

The nymphs perform the duties of workers by foraging, feeding the queen, king, soldiers and the young, and sealing up holes with masticated wood. If the primary reproductives are lost, they can be replaced by several nymphs as secondary reproductives. Although the total reproductive potential of secondary can exceed that of the primary king and queen, these colonies require a long period to reach a size that can do significant damage.

When the workers have developed into alates, they take to the air when the conditions are good to start their own colony. Swarming is the primary way the termite naturally spreads after it has been transported to a new area. Spread by swarming is slow, however, because the termite is a poor flier. Unassisted, it cannot fly more than 1/4 mile. Moreover, the swarmers are attracted to the closest light source.

Swarming usually takes place in June and July but the occasional swarmer can be found at any time of the year. Swarming usually takes place after sundown between the hours of 7:00 PM and 9:00 PM. This can vary. Swarming takes place when there is virtually no wind. During the swarming season the termites will open their flight slits (slits in the side of wood open to the air) and poke their noses out to see if the conditions are right. If the winds exceed 2 mph, then the swarming will not occur. If swarming starts and the wind increases to more that 2 mph, swarming stops. They will then seal the slits with masticated wood and wait for another time.

If the conditions are favorable though, all the alates will leave the colony in a matter of a few minutes and flutter about. Once swarming begins it is usually completed within thirty minutes. At this point something remarkable happens. These insects which spend their entire life in the dark and avoiding the light are now attracted to any light source. Perhaps it is their way of finding each other. After a brief time they drop to the ground and shed their wings. They then go about looking for a mate. Once they are paired off they move around in tandem, with the male following the female. They then look for a place to begin their colony. Fortunately for us, most of the swarmers are eaten by birds, toads, ants, geckos, spiders, or chameleons. Only a very small number survive, perhaps 1 to 2%.

Since they are usually on the ground it is easy to see why they often end up in doors, this being the first piece of wood they come to and the bottoms are untreated and often with holes which allow then access. They like plywood for the same reason that it has holes already in it. They are not deterred if there are no holes in the wood for they will

simply chew their way in. At this point they are not eating the wood but chewing it and leaving the pile of undigested wood shavings on the floor. I had the stairs in my home changed to oak. The carpenter drilled small holes in the oak then pounded finishing nails into these holes before filling them with wood dough. One night during construction I noticed a small pile of fine dust outside one of the drill holes that had not yet been filled. With a light and hand lens I watched as two drywood termites crawled in and out of the hole chewing a small amount of wood and bringing it to the top of the hole and depositing it at the opening. They did not eat the wood. They worked tirelessly excavating a new home for themselves at a steady pace for over an hour until I put an end to their efforts.

III. Habitat

The West Indian termite likes to make its home in most kinds of wood in houses and buildings. Our most common building materials are Douglas fir, oak and redwood and woods like Koa, maple, walnut and other hardwood for cabinets and furniture and all are readily infested. It will bore through books, tarpaper and other material containing cellulose. Since it does not require a source of water for survival, it can be easily transported throughout the world. It infests packing cases, crating lumber, picture frames, boxes, barrels, and wooden articles. In founding a colony the reproductives take advantage of any small crack, joint or hole which they can find and commonly begin their tunneling from such a point. After penetration is accomplished, the male and female tunnel along the grain of the wood, establish a nest and the female lays a few eggs. When the tunnels become crowded, an exit hole or "kick-out" is bored to the exterior and quantities of the fecal pellets are pushed out. When they are finished, they then seal up the hole with masticated wood. Fecal pellets are loose and uniform in color, varying from beige to very dark brown depending on the type of wood consumed. This habit makes the presence of the termites known and is usually the first indication that an infestation exists in any article or situation. The infestation is usually easy to locate directly above any pile of pellets. In houses and other buildings, infestation frequently begin in attics, and spreads to all parts of the structures. Proper screening of all attic openings with a fine mesh screen will aid greatly in reducing infestations.

This termite works in much smaller colonies and much slower than does the Formosan ground termite. In well-established colonies the number of individuals rarely exceeds 300. There was inspection I did in a condominium on the Gold Coast where the plywood closets were infested to such a degree that there had to be an over-lapping of colonies. Opening up the plywood walls there were thousands of individuals. This drywood termite does not cause great damage in short periods of time. Its action is gradual and cumulative but persistent.

Termites spend most of their life in the dark, so that in finding their way about they must rely on senses other than sight. Indeed, it has been discovered within the last few years that termites possess a sense of smell sufficient for them to distinguish between odors which are acceptable and which attracts them and odors which are not acceptable and repel them. It has also been discovered that termites of the same species are able to

communicate with each other in a primitive manner by the laying of scent trails which attract other termites to follow along the same trail. These secretions are known as pheromones and there is no doubt that these trail-laying substances play an important part in the activity organization of the colony. There seems no doubt that this means of communication using chemical odor reception and we must keep in mind that this is taking place entirely in the dark-prevents wandering, dispersal, the intrusion of other species, and perhaps predators.

Drywood termite droppings

The drywood termite colony lives in the piece of wood that also serves as its food source. They have no source of moisture other than the moisture content of the wood which in Hawaii is about eleven percent. Therefore, it is important they retain all of their fluids. To facilitate this they have absorbent pads in their lower abdomen that remove the water in the droppings before they are excreted and keep the termite hydrated. The termite droppings are very dense, hard and somewhat oval shaped. When examined closely small grooves can be seen caused by the muscles in their abdomen when they were being formed. Droppings will generally be the same size and shape but color may vary.

Occasionally debris from ants will be confused with that of termites. The debris from ants is not necessarily their droppings but just bits of material they are moving to clean their dwelling. It is irregular shaped and for the most part is very fine. If ants can gain access to a drywood termite gallery they often make their nest in it and will push out termite droppings. This is frequently the case after a house has been tent fumigated.

The droppings are allowed to accumulate inside the termite galleries until, apparently, word is passed that it is time to clean house. At this point a small 'kick-out' hole is opened from the gallery to the outside and with a collective effort all of the termites will gather the droppings, one-by-one, and push them out the hole. I have observed this behavior on a number of occasions and as quickly as one dropping falls from the hole another tiny termite head appears with a dropping in its mouth and pushes it out. The process continues until the foreman decides enough cleaning has been done. At that point wood is chewed into a paste and the hole is plugged. The paste dries into a brown, brittle door, about as thick as a piece of paper that keeps out small predators such as ants. They may open this hole again at a later date to continue cleaning or open a hole in a different location. Frequently people see a pile of dropping only once and falsely assume the termites have either died or moved away. If they open a 'kick-hole' in the wood and find a piece of sheetrock, hardboard siding or other wall covering they will eat through this material as well. They are not necessarily digesting this material, just chewing through it.

METHODS OF CONTROL, DRYWOOD TERMITES

PREVENTION

If you have an older house made with untreated lumber there is little you can do to prevent them from infesting. Keeping it painted will help but they will find their way in eventually. In my experience they seem to infest a house six to eight years after it is fumigated. When termites swarm turn out the lights and vacuum any that you can see. Paint the tops and bottoms of doors. Cover attic ventilation accesses with fine mesh screen for the termites and metal hardware cloth for the birds that will other wise destroy the screen.

FUMIGATION

The most effective method of control is tent fumigation. There is only one fumigant used for the control of drywood termites in Hawaii and it is VIKANE, Sulfuryl fluoride, manufactured by Dow AgroSciences. It was developed in the 1950's and has been widely used since then. It is a transported as a liquid in pressurized cylinders but vaporizes at 67 degrees Fahrenheit and it is toxic especially to insects. It will control a broad range of insects but it is generally used to control drywood termites as there are usually more inexpensive ways of treating roaches and other pests. Different insects will be killed with different doses of VIKANE so an insect with a high metabolism, such as a fly, will succumb much quicker than termites. Spiders, with very low metabolic rates, will require twice as much fumigant as termites. Another variable is not just the quantity on the fumigant introduced to the structure but the length of time it is kept there. Therefore, a structure can be fumigated for a shorter period of time if the quantity of the fumigant is increased. The dosage also depends on a number of factors such as the type of soil under the building. A house built on sand will require a higher concentration as the gas will settle into the sand more easily than a dense, compact soil. The wind speed can cause the tent to flap and force some of the gas out. Containing the gas with tent that is in good condition and sealing the bottom of the tent so the gas does not leak out around the bottom is imperative. Fumigation of houses is a real blend of science and art. Its objective is to confine a sufficient amount of gas for a long enough time to allow it to penetrate all the areas of the house and kill all the termites. VIKANE is effective not just because it is toxic but because it is able to penetrate deep into the wood through the pores. These pores are so small they can only be seen with an electron microscope. Being able to penetrate into openings this small it can easily penetrate the relatively large termite galleries. This penetration is called sorption. Another desirable quality of VIKANE is its rate of desorption. It does not bind with the wood or anything else in the house and leaves no residue. The gas diffuses from areas of higher concentrations to areas of lower concentrations so while the tent covers the house and contains the gas it moves to areas where there is little or no gas. Once the tent is removed the diffusion continues to the outside where there is no gas until all the gas has escaped. The gas is heavier than air so circulating fans are used inside the house to insure that areas such as the attic and rafters are covered. Once released into the atmosphere it is broken down through hydrolysis. Having done thousands of inspection in Hawaii it is my

experience that fumigation is generally very effective. However, if termites do survive it is usually outside and up high in a fascia or the end of the main beam, away from windows or attic vents.

Since the gas leaves no residue in theory termites can reinfest the next day. This is rarely the case and how quickly they do become established in a structure is dependent upon several factors. If the house is made of untreated lumber then it has many places for the termites to find a home. If it is surrounded by older houses made with untreated lumber then there are multiple places for the termites to come from. Infested items such as furniture should never be brought into the house. I did an inspection on a house that had been tent fumigated less than a year before and found them throughout the hardwood floors. As it turned out the floors had been installed after the fumigation and since this was the only area with termites it was apparent this was how they got there. Apparent to everyone except the company that installed the floors.

Condominiums are often infested, especially older buildings. Condominiums with doors facing outside are much more prone to infestation than those with doors opening to enclosed hallways. This indicates termites are flying in rather than being transported in furniture. I did an inspection in a condo in Nuuanu that had been rented to the same tenant for many years. I met the owner and immediately saw termites in the front door and frame. When we entered there were still imprints in the carpet where furniture had been sitting and there were large piles of termite droppings. Not such a great tenant after all.

DRYWOOD TERMITE SWARMERS

SPOT TREATMENT

Spot treatment can sometimes be effective when there is a limited infestation and it is accessible. An insecticide is injected into the termite galleries. If it reaches the termites they are instantly killed. The problem is getting it to the termites. The biggest failure results when the infestation is large and the insecticide doesn't penetrate adequately or when there are infestations that are not visible. Treating plywood is difficult as the liquid does not penetrate the various layers especially with thicker pieces.

A variation on this is the application of Tim-bor to the surfaces of the wood. Tim-bor is a combination of sodium oxide and boric oxide applied with water. It is used to pressure treat lumber but can also be used by a pest control operator with a license to use restricted use pesticides. According to the manufacturer, applying it to the surfaces of wood will kill termites inside the wood. The limitations are that it can not be used where it will be washed away with rain, it should be applied to an unpainted surface and some infestations may be inaccessible such as those inside walls, between the floors and behind cabinets. The danger here is that the visible infestations have been eliminated but the inaccessible ones continue to damage the structure.

REPLACEMENT OF INFESTED MATERIALS

Replacement of the infested material works but only when you can be sure all the areas of infestation have been identified. This may be appropriate in a condominium when the front door has been heavily infested and damaged and there is little else inside the unit that termites would find palatable.