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# SOLVING TREE SQUIRREL DEBARKING PROBLEMS IN TAIWAN—A REVIEW

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ABSTRACT: Extensive forest conversion of the low-valued natural hardwood forest into coniferous plantations is the possible cause of the critical problem of squirrel debarking. The tree squirrel that causes the major damage is the red-bellied tree squirrel (Callosciurus erythraeus). Conifers are more susceptible to the damage than are hardwood species, especially the exotics. Intermediate-aged plantations appear to have the highest debarking. More damage occurs in the spring than the other seasons. The lower part of the trunk is more heavily debarked than the upper. Debarking is progressively upward to the crown as the tree grows older. Home range, food habit and behavior of the red-bellied tree squirrel are under intensive study and some preliminary results have been obtained.

Selection of tree species less susceptible to squirrel debarking has been a main step to control the damage. Intensive weeding and thinning may reduce much of the squirrel preferred habitat and therefore reduce damage. Leaving any natural hardwood forest within or adjacent to the coniferous plantations may provide squirrels with a more attractive cover and food supply. A rice-paraffin bait block of warfarin has been used to poison them with some success. But laboratory studies show klerat (brodifacoum) has a faster lethal efficacy than warfarin. Application of baits and other trapping methods to control squirrel populations need more study and evaluation.

## INTRODUCTION

Since World War II Taiwan has converted a large area of less productive natural hardwoods into plantations of conifers, often with introduced species. As a result, a serious rodent pest problem was created in the modified ecosystem. Cryptomeria (Cryptomeria japonica) and China fir (Cunninghamia lanceolata) are two important reforestation species in Taiwan which are planted extensively and have suffered badly from squirrel debarking. This has become a major problem in forest protection. Not only the growth rate of the trees is retarded but also the wood quality of the damaged trees is greatly reduced. Squirrel debarking creates a wood decay caused by fungus infection as a secondary damage. Therefore, the squirrel problem has greatly hindered the Taiwan reforestation program. Studies on the causes of squirrel debarking and the ecology and control measures of squirrels have been undertaken and valuable knowledge has been gained. However, we have a long way to go before squirrel damage can be effectively controlled.

## THE SPECIES OF SQUIRREL

We have determined that the major culprit of debarking is the red-bellied tree squirrel (Caliosciurus erythraeus). The other two species of tree squirrels are not suspected of damaging trees. There is strong evidence that some of the flying squirrels may account for some damage such as killing the tops of trees in the forest plantations (Howard 1980, Chang 1981). In Taiwan in the past few years, most of the studies of squirrel damage have been directed to the red-bellied tree squirrel.

In Taiwan, the red-bellied tree squirrel is distributed over the entire island from 500 to 2,800 meters above sea level. However, this squirrel prefers cool but not too cool weather (Chang 1981). Therefore, more are seen at lower elevations than at higher elevations (Wang and Kuo 1980). These squirrels live in very dense, humid forests and are not common in dry sites. It prefers a habitat of evergreen hardwood forest located near a stream or water source (Chang 1981). Higher populations of squirrels can be found in plantations adjacent to natural hardwood forests. That is where the most serious debarking damage in plantations is likely to occur.

## THE ECOLOGY OF SQUIRREL

The nest of the red-bellied tree squirrel is usually found about ten meters above the ground in conifer trees. It does not often nest in the hollows of natural hardwoods (Chu and Yie 1970, Wang and Kuo 1980, Chang 1981). Nests are lined with soft bark and leaves of hardwood trees growing in the conifer plantation. The distance between nests is seven to ten meters and as many as 28 nests, including new and old, are found in one hectare (Chang 1976). The density of the squirrel is about 2.5 per hectare in forest plantations which is to be likely a pest population. The average travelling distance is 244 meters. Home range is estimated to be 3,714 $m^2$ (Lin and Yo 1981) but varies significantly with the supply of natural food, shelter and water (Chang 1981). The quantity, quality and availability of squirrel food vary in different seasons, thereby affecting the carrying capacity of the habitat for squirrels.

Squirrels are omnivorous, but their major diet is plant food, chiefly seeds and fruits. Stomach content analyses showed occurrence of 23 species of plant material, 7 species of animal material and fewer of fungi, soil and minerals. The average proportion of these materials is 94, 5, and 0.5%, respectively. The most abundant food item from February to April is cambium of Cryptomeria, which occurs in 80-100% of the stomach contents of the red-bellied squirrel (Chang 1981). This squirrel prefers fruits with a high sugar and juice content than those of low sugar and juice content (Wang and Kuo 1980).



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As indicated in many reports (Chang 1976, Lin and Yo 1981, Wang and Kuo 1980), there are two peaks of feeding activity during the day, one in the early morning and one in the early evening. Squirrels spend most of their time during the day in the tree and travel in the underbush at midday (Lee 1981). Less damage occurs during the winter due to the plentiful production of hardwood fruits from the natural forests. The summer and autumn seasons also have less damage because of a good supply of passion fruits (Passiflora edulis). The most serious damage occurs in spring when the supply of natural food is low, although tree sap running in the spring may attract squirrels to lick the juice.

Bark-peeling by squirrels is mostly done longitudinally along the trunk. Pieces of stripped bark are dropped and appear scattered over the ground. Squirrels usually come back repeatedly to peel the bark on the same wound until the cambium is reached. Clear tooth-marking can be observed over the bark pieces and wounds on the wood (Wang and Kuo 1980). Damaged trees do not always die; however, young trees die more easily than mature trees.

## DAMAGE CAUSED BY SQUIRRELS

Squirrel damage to forest plantations varies greatly with the species of trees. As a rule, the squirrels strongly select conifer trees for debarking. Therefore, conifers are more heavily damaged than the hardwoods. The introduced conifers most heavily damaged by the tree squirrel in Taiwan are Cryptomeria, China fir, Luchu pine (Pinus luchuensis) and slash pine (Pinus eiliottii). The most seriously damaged native conifers in plantations are Taiwan incense cedar (Calocedrus formosana) and Luanta fir (Cunninghamia konishii), but other native species sometimes damaged in plantations include Taiwan red pine (Pinus taiwanensis), Taiwan white pine (Pinus morrisonicola) and Taiwan red cypress (Chamaecyparis formosensis).

Fruits and flower buds are the main food of squirrels in the hardwood forest, while in the coniferous plantations bark is peeled by squirrels. Young and old plantations have less damage than that of intermediate-aged stands. In the sapling stage, the lower part of the trunk is more heavily damaged. Damage will proceed upward to the crown of the tree as the tree grows older (Wang and Kuo 1980).

Squirrel debarking causes second infection over the wounds one to two years after the damage started. Most wounds do not heal. The earlier the wound or the greater the number of wounds, the greater the decay in the wood. More wounds are located on the lower part of the trunk. The main stem utilization percentage of Cryptomeria and China fir is decreased up to 50% due to wood decay caused by squirrel debarking. Squirrel damage seriously reduces the growth of trees of both species, especially on the volume growth which decreased remarkably as the squirrel damage increases (Kuo 1981).

The actual reason for squirrel debarking Taiwan trees is not yet clear. We believe that it is a wildlife habitat problem and an ecological phenomenon. Squirrel damage has something to do with the natural stability between plants and animals within the forest ecosystems. There are two possible reasons: first, shortage of food supply resulting from clear-cutting of the natural hardwoods and second, extensive harvesting for food and medicine of the wild animals which used to be the natural predators of squirrels. It is good example of the environmental problems and instability that are caused when a complex natural ecosystem is converted to a simple, artificial ecosystem.

## CONTROL OF TREE SQUIRREL

The red-bellied tree squirrel has become a serious problem in forest protection, especially in the national forests, therefore measures have been taken to control their populations. Firstly, as an immediate action of squirrel control, a bounty for squirrel tails was instituted by the Taiwan Forestry Bureau for more than fifteen years. There was no evidence that the bounty helped very much. At least it did not stop the squirrel debarking problem. On the contrary, bounty was indiscriminate. No attempt was made to identify the species doing the damage. Thus, many "innocent" squirrels were also taken. At the same time warfarin bait was used as a poison, but it was relatively ineffective in stopping tree squirrel damage. In 1977, a new formulation of warfarin with rice and paraffin was used. It showed fairly good results in some forest districts. Laboratory tests recently done on klerat (brodifacoum) showed very promising results on squirrel acceptance and killing. It may replace warfarin and become a major poison compound for squirrel control in the future.

Control of squirrel by forestry practice has proved to be a very basic and economically feasible method for the prevention of squirrel damage. It is presently under continuous study in some plantations. Choice of reforestation tree species that are less susceptible to squirrel debarking has been the first step in Taiwan reforestation program to control squirrel damage. Modification of squirrel habitat that reduces the amount of food and cover availability could greatly affect squirrel survival. Pure stands of either Cryptomeria or China fir are more severely damaged. Squirrel damage in the mixed stands of Cryptomeria and China fir is lower than in the pure stands of either tree species. Squirrel damage is high on China fir when it is mixed with Cryptomeria in a stand.

Squirrel damage is low when tree spacing is large. The part damaged by squirrel tends to go up from trunk to tree crown as spacing between trees increases. Dominant trees seem more susceptible to squirrel debarking than the suppressed trees. Dense stands of China fir also show higher damage than sparse stands of the same tree species. Silvicultural treatments including weeding, pruning and thinning seem effective practices in reducing the population density of squirrels, thereby lowering the damage.

Squirrel debarking in coniferous plantations in Taiwan has become a most critical forestry problem and it has spread over a large area of forest land. In order to control the problem both basic and

applied research on squirrels have been undertaken jointly by all organizations concerned. Results obtained from past studies provide us a general picture about the damage, ecology of the squirrel, and possible means of control. Everyone familiar with the problem seems to agree that it is essential to quickly find an effective way to protect forest plantations from serious damage by tree squirrels. Current studies are concentrated in the area of bioecological characteristics of the squirrel and the means of application of poison, i.e., amount, type and placement of the bait in the damaged plantation. In the long run, forest management practices based on wildlife-forest relationships should be a principle to be considered in the control of squirrel debarking. Long-term management of Taiwan forests must consider food requirements of tree squirrels and provide proper habitat that will tend to keep them from invading tree plantations. It is unlikely that poisoning could be applied in sufficiently broad areas to be effective; therefore biological control through management of natural food supplies is necessary. Also, selection of highly resistant individual trees, even of species commonly damaged, is a distinct possibility for controlling squirrel damage through genetic practices.

LITERATURE CITED

CHANG, W.F. 1976. The ecological research of the red-bellied tree squirrel damage to forest in Taiwan. Environmental Research Center, Tung-hai University, Taichung, Taiwan. 34pp. (In Chinese).

. 1981. Study on feeding habit and home range of the red-bellied tree squirrel in Taiwan. Unpublished.

CHU, Y.I. and S.T. YIE. 1970. Some biological notes on the Taiwan squirrel. Plant Protection Bull. Vol. 12, No. 1:21-30. (In Chinese).

HOWARD, W.E. 1980. Visiting expertship report on studies of population ecology of squirrel. Mimeographed, 21pp.

KUO, P.C. 1957. A preliminary survey of squirrel damage to forest trees in Taiwan. Tech. Bull. 12, Expt. Forest of National Taiwan University, 20pp. (In Chinese with English summary).

_____. 1981. The effects of squirrel damage on growth and wood decay. Unpublished.

LEE, L.L. 1981. The behavioral study on the red-bellied tree squirrel (Callosciurus erythraeus), masters thesis (In Chinese), 41pp.

LIN, Y.S. and S.P. Y0. 1981. Population dynamics of the red-bellied tree squirrel (Callosciurus erythraeus). Bull. Inst. Zool., Academic 20(1):31-41.

WANG, T.T. and P.C. KUO. 1980. Squirrel damage to economic forest in Taiwan — relation between squirrel damage and the species and age of forest plantation, National Science Council Monthly Vol. VIII, No. 6:527-550. (In Chinese with English summary).

_____, B.T. CHEN and W.L. LI. 1981. Effects of forest composition of squirrel damage in coniferous plantations. Unpublished.