

Steremnius carinatus (Boheman)
in the Vancouver Forest Region:
A review of available information

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Introduction

Steremnius carinatus (Boheman) (Coleoptera: Curculionidae), a native forest insect formerly considered an insignificant scavenger, has since developed into a forest pest due to the alteration of the forest environment. The harvesting of forest stands provides the indigenous weevils with an abundant supply of breeding material, roots of stumps and buried slash, favouring massive population increases (Condrashoff 1968). The subsequent planting of seedlings for reforestation provides the weevils with a ready food source. The seedlings are girdled by adult feeding at the root collar which results in mortality, reduced plantation stocking, and, in severe cases, plantation failure.

S. carinatus is found throughout coastal forests from Alaska to California where it normally feeds on a variety of plant material (Doane et al. 1936). In addition to coniferous seedlings, it is also known to feed on

other ground vegetation such as fireweed, salal and blueberry (Condrashoff 1968). This seedling weevil was first recognized as a forest pest in 1961 by foresters of MacMillan Bloedel Ltd. where it was causing serious damage to newly established Douglas-fir, Pseudotsuga menziesii, plantations near Kennedy Lake, Vancouver Island (Lejeune 1962). This type of damage had previously been attributed to field mice.

Similar types of forest plantation damage involving hylobiid weevils are not uncommon. Hylobius abietis Linnaeus has long been identified as an important pine plantation pest in Europe (Nordic Forest Entomologists Research Group 1962). Hylobius pales (Herbst) (Carter 1916; Peirson 1921; Friend and Chamberlin 1942; Finnegan 1959), and, Pissodes approximatus Hopkins (Finnegan 1956, 1958) are important pine plantation pests in eastern Canada and United States. Hylobius congener D.t. has recently been identified as a pest of newly established plantations in parts of the Maritimes (Magasi 1986, 1987).

Although S. carinatus is found throughout western coastal forests, and 'wet-belt' interior forests, significant damage to plantations has been primarily confined to cool, damp forest types along the west coast of Vancouver Island, and, in the Queen Charlotte Islands (Condrashoff and Kinghorn 1963).

Seedling mortality in newly established plantations can range as high as 40% to 50% (Craven, pers. comm.; Voth 1982). Most damage occurs during the first year after planting with spring and autumn being the periods of heaviest feeding (Condrashoff and Kinghorn 1963; Condrashoff 1964b, 1968, 1969). Outbreaks flare-up sporadically in isolated localities for a few years then

diminish to low levels (Wood and Vallentgoed 1985; Waugh 1986).

S. carinatus may in fact be causing a higher level of seedling damage than is currently acknowledged, due to the lack of recognition during planting assessment and survival surveys.

Biology of Steremnius carinatus

Life cycle

The life cycle of S. carinatus generally requires just over one year to complete (14 plus months); the rate of brood development being greatly influenced by temperature. In logged sites exposed to the sun, eggs laid in the spring emerged as adults in the summer of the following year (Condrashoff 1968). Broods established in the spring within a shaded uncut forest did not produce emerging adults until the spring two years later.

Overwintered adults mate and lay eggs. Young adults do not mate until the year following emergence. Eggs are laid from midspring to midsummer, peaking in May and June, in niches chewed under bark scales of stump roots and in buried slash. The cool, moist interface in the deep litter zone surrounding the stumps seems to be the preferred brood areas (Carlson 1983). In the natural forest situation, they breed in roots of wind broken trees. Live trees or trees with dead crowns are unattractive to the weevil. Roots of stumps can remain suitable for weevil development for several years after felling (Condrashoff 1964a, 1968).

Douglas-fir, Pseudotsuga menziesii (Mirb.) Franco, and Sitka spruce, Picea sitchensis (Bong.) Carr., are the preferred hosts for brood establishment, however, western hemlock, Tsuga heterophylla (Raf.) Sarg., and amabilis fir, Abies amabilis (Dougl.) Forbes, are also utilized (Condrashoff 1968). Western red cedar, Thuja plicata Donn, and red alder, Alnus rubra Bong., are unattractive to the weevil.

After hatch, the larvae mine through the bark to the phloem where they construct irregular galleries, complete their development and pupate. Immature stages have been described by Condrashoff (1966). Adults generally emerge in mid to late summer. Young adults are usually brick red while older adults fade to yellow or brown. The adults are long lived, capable of overwintering at least three times and establishing broods each year (Condrashoff 1969).

A related species, Steremnius tuberosus Boheman, is often associated with S. carinatus causing similar damage but is less numerous. Its biology and habits are also very similar (Condrashoff 1968). Condrashoff (1964a) suggested that these two species are similar enough that both may be considered as one problem.

Dispersal

Utilizing adults marked with fluorescent paint, Condrashoff (1968) found weevil dispersal after 5 1/2 months (27 September to 11 March) to generally remain within 61 meters (200 feet). At another location, marked weevils were

also recovered within 61 meters from the release point after two weeks. Although flightless, their elytra are fused, it was believed that at this rate of crawling the weevils could easily invade adjacent plantations or recently harvested settings (Condrashoff and Kinghorn 1963).

Mortality factors

The predator and parasite complex associated with S. carinatus has not been adequately studied. The fact that broods are generally located in roots below ground level likely reduces the opportunity for predation or parasitism typical of Hymenoptera and Diptera insects. There are, however, most likely at least a few adapted parasites or predators which can affect weevil broods.

Condrashoff (1968) stated that large carabids are likely predators of adult weevil. Although they were not observed attacking weevils, they were often found near baited traps. Spiders were observed to attack and feed on adult weevils in greenhouse enclosures and cages, and it is likely that weevils are predated upon in the field by spiders.

Clerid and other Coleoptera larvae also prey upon Steremnius larvae, and, nematodes and mites were found under adult elytra and on larvae (Condrashoff 1968). In addition, competition from other weevil and scolytid larvae within stump roots may be intense.

Adult weevils showed a remarkably high survival rate when subjected to cold temperatures (25 hours at minus 4.0 degrees Celsius, and 8 hours at minus 8.9

degrees Celsius) (Condrashoff 1968). Cold temperatures in the field are unlikely to have a significant impact on the mortality rate of these weevils.

Adult feeding behaviour

These omnivorous weevils commonly occur in undisturbed natural forests at low population levels where they feed on a wide variety of different plant materials containing starches and sugars (Condrashoff 1968). Adults will feed on fireweed (with a preference for dead plants), huckleberry, salal, dried and browned coniferous foliage, and phloem tissues from fire scorched bark peeling from stumps and slash.

Young naturally regenerated and planted conifer seedlings are also fed upon. The phloem on the stems near the root collar, 1 centimeter below, and 2.5 centimeters above ground level, is eaten (Condrashoff 1968). Most native conifers are attacked and can sometimes be stripped for several inches up the stem (Condrashoff and Kinghorn 1963). Although it has been stated that Douglas-fir and Sitka spruce are preferred for adult feeding (Furniss and Carolin 1977 ; Humphreys and Ferris 1978), amabilis fir was found to be the preferred host on northern Vancouver Island (Voth 1983). Cedar appears to be less preferred (Humphreys and Vallentgoed 1986; Waugh 1986; Wood and Vallentgoed 1985). Beaumont (undated) found hemlock to be the most heavily attacked and Sitka spruce the least attacked.

Feeding is usually confined to seedlings 2 years old and younger (Condrashoff 1968), and there may be a preference by the weevils for weakened or dead

seedlings (Condrashoff 1964a). An interesting point to note regarding feeding preference is that in preference tests involving various fruits and Douglas-fir phloem, banana was preferred over any other food material (Condrashoff 1968).

Condrashoff (1968) reported that less damage occurred where ground vegetation was plentiful, however, in a mixed species plantation near Holberg on Vancouver Island, that apparently had much natural ground vegetation at the time of planting, weevils seemed to have a preference for the planted stock over other vegetation (Voth, pers. comm.). This could possibly be the result of nursery grown seedlings, which are nutrient rich due to the fertilizer regime they are grown under, being preferentially attractive to the weevil.

Fewer seedlings appear to be damaged when growing on bare mineral soil than those growing in organic soil or duff (Condrashoff and Kinghorn 1963). Presumably, the weevils require the cover of duff for protection and retreat.

Heaviest feeding occurs during wet periods primarily during the spring and autumn, and usually at night. During these periods the weevils will feed continuously on cloudy or rainy days, but, usually cease feeding in the early morning on clear days (Condrashoff and Kinghorn 1963; Condrashoff 1968).

During dry, warm periods of the day and during the summer, the weevils hide in the duff. Feeding continues into the middle of November or until the onset of frosty weather when the weevils hibernate deep in the duff until the following warm season (Condrashoff 1968).

In lab tests, the rate of feeding increased up to 17 degrees Celsius (Condrashoff 1968). Also, weevils were found to continue feeding, although just barely, at temperatures as low as 1 degree Celsius (Condrashoff and Kinghorn 1963).

Seedling Damage

The change in status of S. carinatus from insignificant scavenger to plantation pest was not the result of any sudden increase in abundance, but, rather the result of a shift in reforestation practices. Prior to the late 1950's, the planting of seedlings for reforestation was generally not practised on freshly logged sites. Planting was usually only carried out in areas which were not satisfactorily restocked after a period of time with natural regeneration. After about 1960, the practise of promptly planting logged sites within one or two years after logging increased substantially. This strategy, to maintain the productivity of the site and to prevent the take over by brush, unfortunately, sometimes results in the newly emerged weevils and the freshly planted seedlings arriving on the site at the same time. These new expenditures also resulted in a higher value being placed on the seedlings.

Weevil damage, and subsequent seedling mortality, can result in unacceptable stocking levels and, in severe cases, plantation failure. Damaged sites often require replanting and the added expenses associated with it. The common practice for dealing with this pest, fill-in planting, often results in similar damage to the freshly planted seedlings, perpetuating more planting.

These weevil caused regeneration delays can then lead to compounding problems associated with brush competition.

Fortunately, not every cutblock has weevil problems nor is at risk. Relatively few situations require remedial or preventative treatments, or modified planting schedules. Nevertheless, S. carinatus can cause significant problems in some areas. Outbreaks of weevil damage can flare-up seemingly sporadically in isolated localities for one to three years then diminish (Wood and Vallentgoed 1985; Waugh 1986). Reasons for this are not well understood.

Incidences of severe damage have generally occurred in plantations established 2 to 3 years after timber cutting (Condrashoff 1968), a period which corresponds to the developmental span of one or two generations of weevil. Most of this damage occurs during the first year after planting; little damage occurs after the first growing season. Natural and planted seedlings are attacked which can be partially or completely girdled. Planting stock younger than two years old are more heavily damaged than older stock, which is usually only partially girdled (Condrashoff 1968). Bark thickness on the older seedlings may be a factor. 2-0 stock is less frequently attacked, and is less damaged, than 1-0 stock (Condrashoff 1968). Surveys conducted on northern Vancouver Island also confirm this (Voth 1984; Humphreys and Vallentgoed 1986). Beaumont (undated) noted that fall planted 2 + 1 and 2 + 0 stock were unattacked while spring planted 2 + 0 received significant damage. Bare root planting stock also seems to be fed upon less than plugs (container grown seedlings) (Condrashoff 1969; Wood and Vallentgoed 1985; Humphreys and Vallentgoed 1986). Some seedlings damaged in the spring can heal over, or

new buds can develop below the injury, however, completely girdled seedlings usually die (Condrashoff and Kinghorn 1963).

Although S. carinatus is found throughout coastal forests from Alaska to California, its geographic range of damage within the Vancouver Forest Region appears to be primarily confined to cool, wet forest types along the western half of Vancouver Island, and in the Queen Charlotte Islands. Representative areas which have experienced significant weevil damage are: Justkatla and Deana River in the Queen Charlotte Islands; on Vancouver Island, the Holberg/Winter Harbour area, Juene Landing, Benson Lake, Oktivanch River, Gold River, Kennedy Lake, Franklin River, San Matea Bay (Alberni Inlet), Nitnat River, Caycuse, Gordon River, Wilson Creek and Port Renfrew. (Condrashoff and Kinghorn 1963; Condrashoff 1964a, 1968; Beaumont (undated); Wood and Vallentgoed 1985; Humphreys and Vallentgoed 1986; Waugh 1986; and, additional F.I.D.S. and B.C.F.S. survey info.).

Severity of weevil attack can be highly variable within any one locality. Attack levels ranging up to 90% have been recorded (Humphreys and Vallentgoed 1986), however, average levels of attack, within a locality experiencing weevil damage usually range around 5% to 20%. The amount of mortality associated with this damage generally averages around 5% but can range as high as 50% (Craven, pers. comm.).

Condrashoff (1964a) stated that since weevil populations are affected primarily by the availability of breeding material and food, which are, in turn, dependent largely upon local influences such as logging, general trends

in numbers over large areas are not discernible. However, over a period of time, some relationship with climatic influences may become apparent.

An attempt was made by the author to map the occurrence and intensity of weevil attack from previous survey records to potentially display trends of attack related to biogeoclimatic zones as described by Nuszdorfer et al. (1985). Unfortunately, an insufficient number of the survey records were of a good enough quality to adequately carry this out. Either the locations were not precisely recorded, or the attack levels were not noted. However, the information that was available did seem to concur with Condrashoff and Kinghorn (1963) that most damage occurs within cool, damp forest types. The biogeoclimatic zones which appear to be involved are the Southern Variant of the Hypermaritime Coastal Western Hemlock Biogeoclimatic Subzone (CWHd₁), and, the Windward Submontane Maritime Variant of the Wetter Coastal Western Hemlock Biogeoclimatic Subzone (CWHb₁). Within the Queen Charlotte Islands, the Submontane Variant of the Queen Charlotte Islands Coastal Western Hemlock Biogeoclimatic Subzone (CWHg₁) is likely involved (Banner, et al. 1983). Although no reports of damage were available from the Mid-Coast Forest District (Bella Coola), it is likely that undetected damage has occurred here within similar biogeoclimatic zones. Little damage has been noted in the relatively drier zone, the Wetter Coastal Douglas-fir Biogeoclimatic Subzone (CDFb) and the Vancouver Island variant of the Drier Maritime Coastal Western Hemlock Biogeoclimatic Subzone (CWHa₁) (Humphreys and Vallentgoed 1986).

Utilizing lindane-poisoned pieces of fresh bark (7.6 cm by 20.5 cm) to sample adult weevil populations, no definite relation between numbers of weevils

caught and incidence of damage was apparent (Condrashoff 1968). Catches of 30 or more weevils per 10 traps, however, may indicate potential damage. Based on trap catches of previously released marked weevils, Condrashoff (1968) estimated weevil populations at 7,000 and 15,000 or more per acre in logged sites which experienced seedling damage.

Factors associated with weevil risk and hazard

As discussed in the previous section, S. carinatus seems to require a cool, damp environment before damage to seedlings becomes significant. The biogeoclimatic subzone CWHb₁ and CWHd₁ on Vancouver Island seem to have a high hazard for weevil damage. More site specifically, an area containing a high proportion of unsuitable tree hosts for breeding, such as cedar and alder, would have lower hazards, and vice versa, an area with a high proportion of suitable breeding material would have a higher hazard.

The abundance of natural herbaceous vegetation on a site after logging, providing alternative food sources, has often been attributed as a major factor determining the degree of seedling damage. Less damage has been noted when ground vegetation was plentiful, even when weevils were numerous (Condrashoff 1968). Slash burning has also been identified as a factor for similar reasons; burning destroys most vegetation on the site, so when seedlings are subsequently planted, they become, virtually, the sole food source for the weevils. There is, however, uncertainty about this concept, as some areas with an apparent abundance of such vegetation have been significantly damaged (Voth, pers. comm.). Burning may also sanitize the site of weevils, thereby reducing the immediate risk of damage.

Within environments suitable for weevil development, logging practices and history, and subsequent planting practices seem to be the major factors contributing to weevil damage (Condrashoff 1964b). Plantations containing freshly planted seedlings which are adjacent to previously cut over areas with large weevil populations will likely also be attacked. Although these weevils cannot fly, it is believed that their longevity and rate of crawl are sufficient for migration (Condrashoff and Kinghorn 1963). Also, the construction of road right-of-ways a year or two prior to timber harvesting has been noted as a factor which can contribute to increased weevil damage (Condrashoff 1969). Indigenous weevils can breed in right-of-way stumps. The emerging adults from these broods can then move into the newly harvested areas around the right-of-way to breed further. The newly established plantation then starts with an above normal population of weevils. Higher levels of attack have often been found next to road right-of-way (Condrashoff and Kinghorn 1963).

The timing of planting can also affect the amount of damage incurred. Seedlings planted after weevil populations have expanded, after breeding in stump roots, may be severely damaged. For example, if planting was conducted during the autumn following the second spring after harvest, seedlings could be subject to heavy damage from newly emerged adult weevils (eggs were laid by indigenous weevils during the first spring after cutting). Conversely if planting was carried out during the first spring after logging, the seedlings would experience two growing seasons before the heavy fall feeding period of the recently emerged new weevil generation and may escape serious damage. Additional herbaceous ground vegetation would also have been established by this time providing alternative food sources.

Planting quality and the planting stock used can also influence weevil damage. Condrashoff (1964a) suggested that weevils may prefer to attack seedlings weakened by planting stress. If seedlings are planted poorly, or are otherwise stressed, the amount of damage experienced may be increased. Recovery from partial girdling would also be suppressed. Planting young stock (i.e. 1 + 0) would increase the risk of damage over older and larger stock. The conifer species planted, unless possibly cedar, would likely not significantly affect damage levels.

In one site on Vancouver Island which recently experienced severe weevil damage, felled and bucked logs were allowed to remain on the site for 3 or 4 years before removal. Subsequently, planted seedlings were heavily damaged. It may have been possible, because weevils can breed in slash, that this additional breeding material was responsible for the apparent high number of weevils on the site.

All of the above discussed factors can act together synergistically, or even antagonistically, to affect the risk of weevil damage. There appears to be, however, an unknown factor, or unknown combination of factors, which allows, or causes weevil populations to flare-up for a number of years in a particular locality. This effect may be the result of a climatic/parasite or disease complex and/or the result of an accumulation of effects from harvesting practices.

Damage Prevention and Control

One of the primary requirements in developing a management system to deal with forest pests is the development of a method to assess the hazards and risks of damage caused by them. To date, this has not been accomplished for Steremnius carinatus. However, Condrashoff (1964b) did develop, for testing, a tentative method to rate these hazards (Table 1). Unfortunately, this work was not completed.

Condrashoff's hazard rating chart was primarily designed for "damp, cool coastal areas," i.e. the biogeoclimatic zones with the highest climatic hazards (CWHd₁ and CWHb₁), however, other areas with similar conditions should not be disregarded.

This method rates the potential weevil damage hazard to seedlings planted on a particular setting in the autumn or the following spring. Based on life history studies and field observations, it uses the time at which road right-of-ways or adjacent settings were felled and the time at which the setting to be planted was felled. It incorporates the longevity of weevils, their ability to establish broods annually, the period required for brood development, and stump deterioration. Extreme hazard occurs when right-of-ways or adjacent settings were felled six years previously, and the setting to be planted was felled three years previously, the optimum timing for weevil immigration and population build-up. Low hazards occur when adjacent settings or right-of-ways were felled six years or more ago and the

setting to be planted was also felled six years ago, or within the current or previous year.

Recommended to help verify the chart ratings was the placement of 10 insecticide-treated fresh bark traps set out for 15 days in September or October, before planting (Condrashoff 1964b). When a rating is medium to high, with a capture of more than a total of 30 weevils, 2-0 stock was recommended for planting. When a rating is high, with more than 80 weevils trapped, 2-0 stock should be planted in the spring following harvesting. When the hazard is extreme or extensive, 2-0 stock stem treated with DDT-latex paint was tentatively recommended.

Information regarding the success of this preliminary hazard rating chart is too limited to assess. Beaumont (undated), however, found that of seven plantations rated with this chart, only two actually received the level of damage predicted. The predicted hazard was higher than the actual damage on four of the remaining plantations and lower on one plantation. The hazard rating, though, does not necessarily indicate the presence of weevils, or, therefore, damage, but only suggests the probability of occurrence.

A similar tentative risk rating key for damage from Hylobius congener has been developed in the Maritimes (Pendrel 1987).

Methods to deal with or control Steremnius damage which have been proposed and attempted are varied and have to date generally been unsatisfactory or inadequately tested.

Condrashoff and Kinghorn (1963) suggested that planting in excess of the number required would help ensure adequate stocking after weevil attack. Although it may appear extravagant, they stated that it might be justified where high site lands are involved and would be cheaper than replanting after weevil damage. Unfortunately, weevil damage does not occur homogenously over a plantation. With this method, portions of the plantation would still likely become understocked while other unattacked areas would become overstocked, both of which would require remedial treatments.

Replanting damaged areas, although necessary after weevil attack, and, commonly employed to deal with this weevil, is an unsatisfactory procedure. It allows unacceptable losses and expenditures. Often, the replanted seedlings are subsequently attacked as well.

The practice of waiting one or two years after burning before planting in areas known to have weevil problems (Pearson 1986) may accentuate the problem by allowing immigrant weevils time to breed and build to high numbers prior to planting. On the other hand, slashburning may render most stump roots unsuitable for broods. Study of the effects of slashburning on weevil populations have either not been done or have not been reported.

Condrashoff and Kinghorn (1963) proposed a planting delay of three or four years after logging and slashburning where damage is predicted to be excessive, and if other palliative measures are not satisfactory. They also recommended, that because the weevil continues feeding into early winter, starts feeding again in early spring, but generally stops feeding during the

summer, late spring plantations would be less damaged than those planted earlier. Late spring planting would reduce the time seedlings are exposed to high weevil activity and once stem growth commences, they suggest, the seedling would have a good chance of overcoming partial girdling. Condrashoff (1968) further recommended that spring planting be carried out immediately following logging and slashburning to allow seedlings to become established before broods of weevils emerge from stumps.

The use of 'jumbo' stock has also commonly been recommended as a means of preventing seedling damage. The older and thicker bark may be a deterrent to weevil feeding. These older and larger seedlings are expensive to grow and more costly to plant, however, in certain circumstances would likely solve the problem.

Similar weevil problems, long recognized in pine plantations of the southern United States and Europe, have adequately been overcome by dipping seedlings in insecticides before planting (Condrashoff and Kinghorn 1963). Testing of several top-dip treatments for protecting Douglas-fir seedlings from Steremnius feeding using DDT and Heptachlor was apparently tried (Condrashoff and Kinghorn 1963). Seemingly these tests were inconclusive due to a general reduction in the weevil population of the test sites (Pearson 1981).

Condrashoff and Kinghorn (1963) further stated that pre-planting dips promise to be the most satisfactory solution to the weevil problem. The cost would be low and the method simple. Undoubtedly there are insecticides today which would work (i.e. Imidan (phosmet) which is registered in the U.S. for such use, but not in Canada), however, the social attitudes of the early sixties

were much different than those of the late eighties. Today, the logistics of such an insecticide use would be more complex. Nursery workers and tree planters would also likely be strongly opposed to handling such insecticide treated seedlings. Regardless, this method has potential and should not be overlooked.

The use of weevil baits similar to commercially available baits to control home and garden weevils, i.e. Otiorhynchus ovatus and O. sulcatus, has also been proposed (Condrashoff and Kinghorn 1963). Tests which used small amounts of bait placed around individual seedlings were apparently initiated, however, no record of the test has been reported. Condrashoff and Kinghorn (1963) believed, that used in this manner, the bait would be a seedling protectant rather than a population control treatment.

Condrashoff and Kinghorn (1963) also tried employing a 'diverting crop' to divert weevil feeding from the valuable seedlings. Although their initial testing did not prove promising, the fact that autumn sown Austrian winter peas and vetch seed were dramatically fed upon by the weevil, implies that these, or other materials, might be used as a weevil bait. They proposed that seed treated with an insecticide could initially serve as a poison bait and, later, the germinants might serve to divert the feeding weevils.

Pine oil, a by-product of the wood pulping process, used as a repellent, has been reported to be an effective deterrent against attack by a number of various forest beetles (Nijholt 1980; Nijholt and McMullen 1980; Nijholt et al. 1981; Alfaro et al. 1984). Two methods of pine oil application were

tested as methods to protect amabilis fir seedlings from attack (Nusdorfer and Heppner 1985). Neither of the two treatments sufficiently reduced weevil damage.

Screefing, the removal of the loose layers of the forest floor from around each seedling, has also been tested (Nusdorfer and Heppner 1985). It was hoped that the removal of this layer would discourage the weevils from approaching and feeding on the seedlings. Unfortunately, this technique also failed to adequately reduce weevil damage. Prescription burns to eliminate these litter and loose duff zones have also been suggested (Carlson 1983).

Plant collars have been found to be effective physical barriers preventing damage caused by Hylobius weevils in Sweden (Lindstrom 1984). However, protective collars have not been tried with S. carinatus.

Conclusions and Recommendations

It is difficult to determine the magnitude of damage caused by Steremnius carinatus. Although, from time to time, it causes significant losses in specific locations, overall it has not been reported to cause widespread damage. Records of damage, in fact, have generally been inconsistent and poorly recorded. There is currently no organized system to record and store Steremnius damage information, and most of the information previously collected by Condrashoff in the 1960's is not available. As a result, S. carinatus has been a neglected insect since the 1960's with respect to

forest pest management research. No management systems or control procedures have been adequately developed. There seems to be, however, a good opportunity for their development. Also, it is suspected by the author, Steremnius damage may be more prevalent than is currently recognized. Plantation assessments which currently attribute poor seedling survival to poor stock may, in fact, be the result of Steremnius feeding.

Damage by this weevil is also currently difficult to predict, as no developed hazard or risk rating system exists. Steremnius damage, for unknown reasons, seems to flare-up in a particular area for a number of years, causing significant damage to newly planted seedlings, then subside to negligible levels. As a result, preventative measures are difficult to enact.

Recommended strategies to deal with Steremnius losses, based on current knowledge, are essentially those presented by Condrashoff in 1968. In areas which have a known or predicted high hazard of weevil attack, planting should be conducted in the spring immediately following harvest. Harvesting should, therefore, be scheduled to complete in time to facilitate spring planting. Also, in these areas, harvesting should not commence before summer, as stumps suitable for weevil brood development would be made available in the spring prior to the completion of harvesting. If these procedures are followed, spring planted seedlings would then experience two growing seasons prior to the heavy autumn feeding period of newly emerged weevil broods. Larger and older planting stock, as is feasible, should be used.

For plantation which have currently experienced weevil losses and require replanting or fill-in planting, 'jumbo' stock is recommended. Regular planting stock will likely be re-attacked. If 'jumbo' stock is not available, the plantation should be left for three or four years before replanting; weevil populations will have likely subsided by that time. This later recommendation, of course, may lead to brush problems at the time of the second planting.

It is acknowledged that the necessities of harvesting procedures can often override weevil hazard concerns. Harvesting operations are much more costly than the potential losses posed by Steremnius weevils, however, the recognition of weevil hazards beforehand could minimize weevil damage through the scheduling of harvesting and planting operations.

Recommendations for future research and development are as follows:

1. A system to collect, collate, store and retrieve Steremnius damage information should be developed. This information will help to recognize trends and to better determine the magnitude of Steremnius losses. It should be built-in as a follow-up step to plantation assessment surveys. Personnel conducting these assessments should also be informed to specifically look for Steremnius damaged seedlings.
2. Condrashoff's (1964b) hazard rating chart should receive further developmental work. Logging and planting histories of areas which have experienced weevil damage should be compiled and studied to help verify, test and refine this hazard rating method.

3. An improved trapping system should be developed to augment and verify hazard ratings, and, also, to relate weevil populations to damage.
4. Operational field trials utilizing spring plantings, 'jumbo' stock and other stock types should be conducted.
5. The effects of slashburning on weevil populations should be studied. Slashburning likely sanitizes the site of resident weevils, reduces litter and duff layers, and decreases the suitability of stumps for brood development.
6. The feasibility of using insecticide treated seedlings should be investigated. This technique could have excellent applicability when replanting sites with high weevil populations.
7. The practicality of using collars as physical feeding barriers around seedlings should be looked into (i.e. Lundstrom 1984) with possible field trials.
8. Because S. carinatus has shown feeding preferences for certain food materials (i.e. banana, peas, vetch seed) the possibilities of using baits to both control weevil populations and protect seedlings is worthy of further investigation.

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