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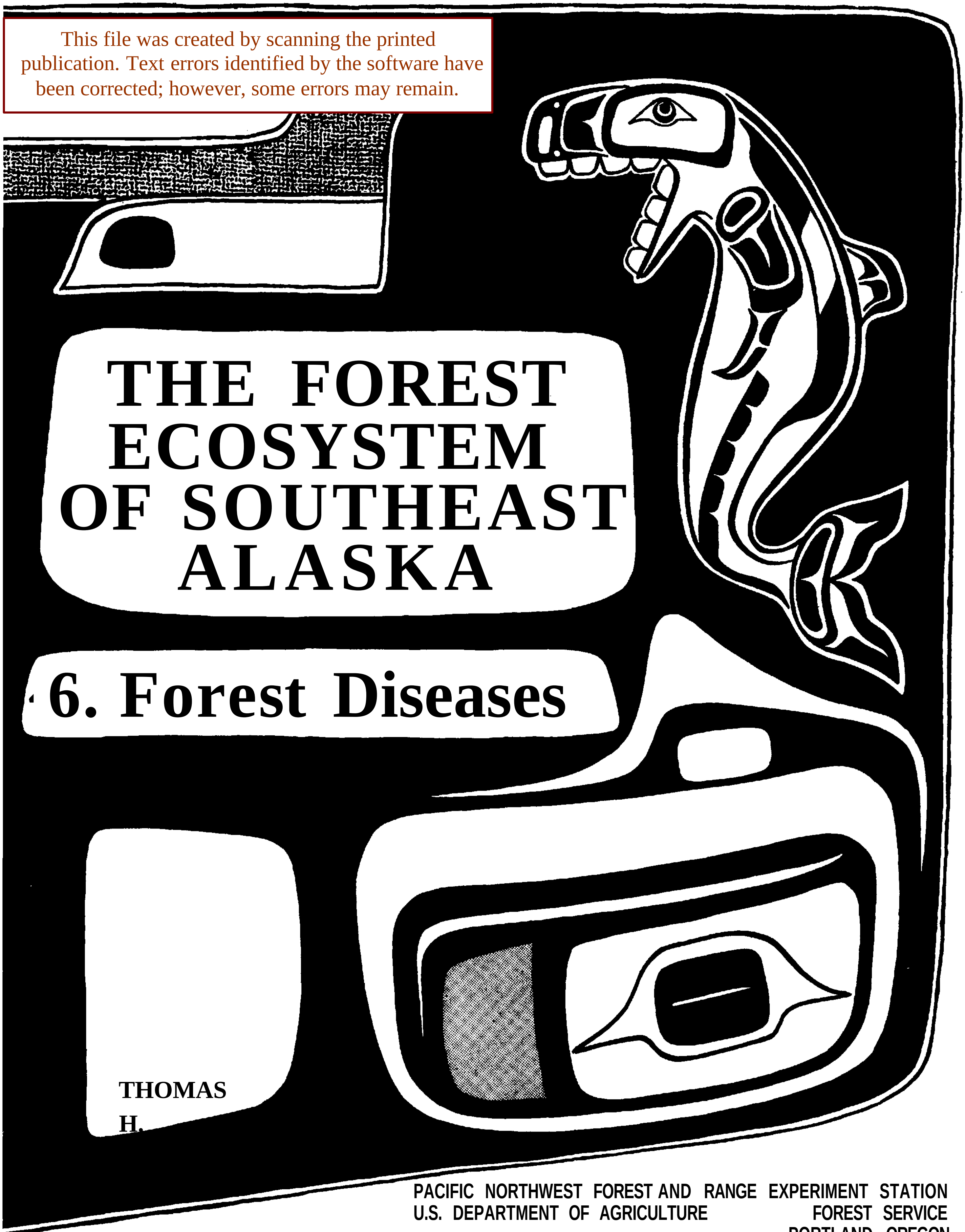


THE FOREST ECOSYSTEM OF SOUTHEAST ALASKA

6. Forest Diseases

THOMAS H.

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

ABSTRACT

Reports on the "state-of-the-art" in respect to forest disease in southeast Alaska.

Keywords: Forest disease. southeast AZaska.

CONTENTS

Author

Thomas H. Laurent. *Plant Pathologist*
U.S. *Forest **Service.** Region 10, Juneau. Alaska*

PREFACE

This is the sixth in a series of publications summarizing howledge about the forest resources of southeast Alaska.

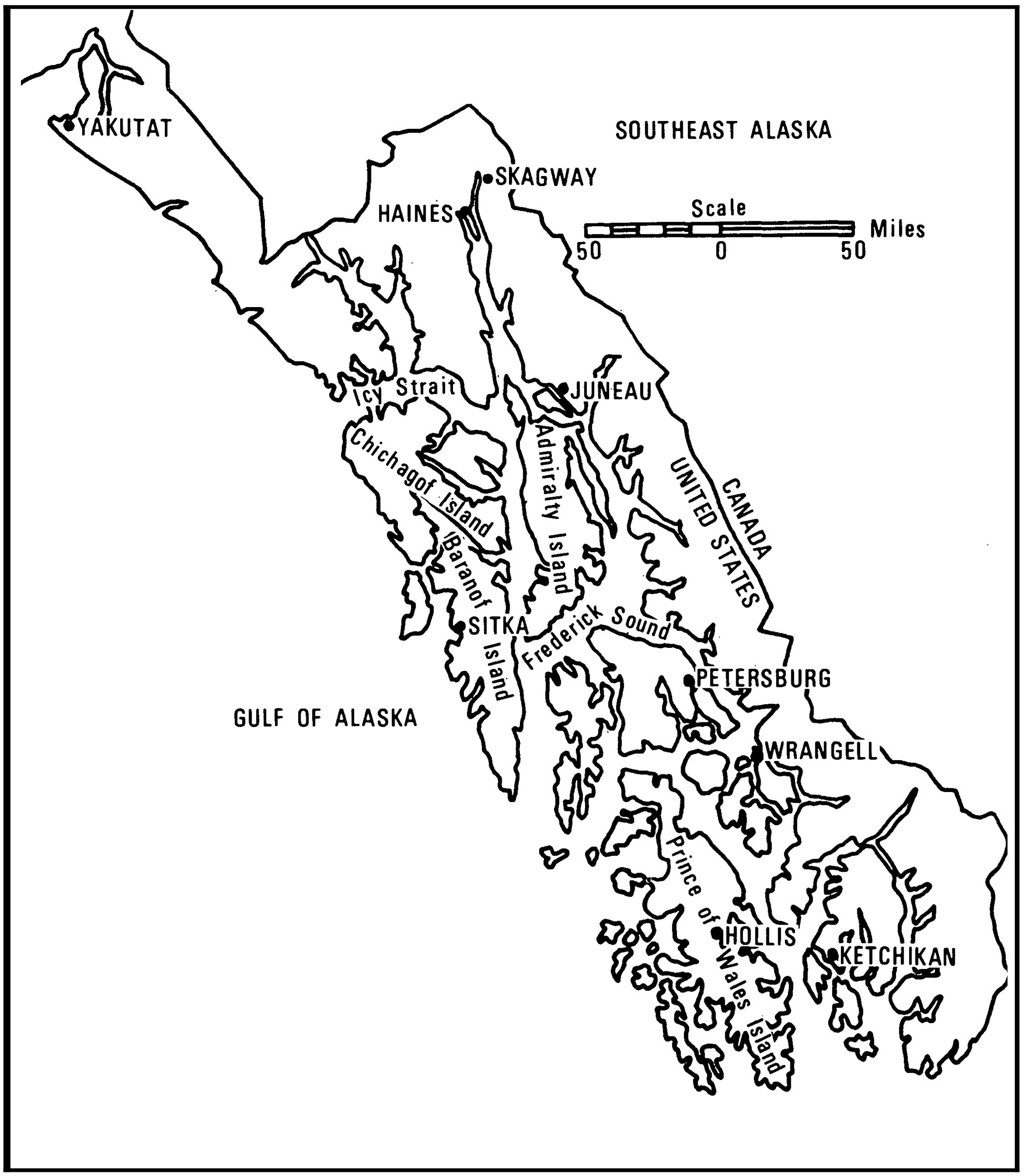
Our intent in presenting the information in these publications is to provide managers and users of southeast Alaska's forest resources with the most complete information available for estimating the consequences of various management alternatives.

In this series of papers, we summarize published and unpublished reports and data as well as the observations of resource scientists and managers developed over years of experience in southeast Alaska. These compilations will be valuable in planning future research on forest management in southeast Alaska. The extensive lists of references will serve as a bibliography on forest resources and their utilization for this part of the United States.

Previous publications in this series include:

1. The Setting
2. Forest Insects
3. Fish Habitats
4. Wildlife Habitats
5. Soil Mass Movement

ROBERT E. BUCKMAN, Director
Pacific Northwest Forest and Range
Experiment Station
Portland, Oregon



Map of southeast Alaska east of the 141st meridian.

INTRODUCTION

All forests at all times are subject to disease[1] causing a loss of merchantable volume by death, decay, reduced growth rates, and decreased viable seed.

In southeast Alaska the disease problem is somewhat simplified in that presently only four tree species are commercially important. In order of volume these are western hemlock *(Tsuga heterophylla* (Raf.) Sarg.), 64 percent; Sitka spruce *(Picea sitchensis* (Bong.) Carr.), 28 percent; western redcedar *(Thuja plicata* Donn), 3 percent; and Alaska-cedar *(Chaecyparis nootkatensis* (D. Don) Spach), 3 percent. At the present time most of the attention is directed toward hemlock and spruce as a pulp source and as squared timbers for remanufacture elsewhere. Decays are of primary importance since the stands are essentially old growth. Hemlock dwarf mistletoe (*Arceuthobium tsugense* (Rosendahl) G. N. Jones) and a complex of low level endemic diseases are of lesser economic importance.

DECAY

Decay caused by heart and root rotting fungi is probably the greatest single cause of volume loss in the forest of southeast Alaska at this time.

The decays not only cause losses due to destruction of wood, but also increase logging and milling cost and complicate management by introducing errors in yield and cruise computations.

There are two broad classes of decay, white rots and brown rots, which are based on the wood components destroyed. The white rots decompose all constituents of the wood, but in the early stages usually only lignin is decomposed; thus the wood is sometimes usable—in pulp for instance. The brown rots attack the cellulose, leaving the lignin more or less unaffected. Wood, in even the earliest stages of brown rot, is useless for pulp or construction. As with other classifications, those of white and brown rots are a bit loose.

Cull factors (describing the distribution of sound wood in mature trees) for the major tree species in southeast Alaska were published by Kimmey in 1956. Two types of decay factors were developed--flat factors, which distribute the cull throughout the stand by diameter class regardless of any external indication of decay, and indicator factors, which are based on external indicators such as fungal fruiting bodies or wounds. In the area sampled, the amount of cull associated with the indicators did not vary appreciably. For greater reliability Kimmey suggests that the flat factors should be based on a larger number of study areas. He also suggested that the indicator factors be used rather than the flat factors. Tables were furnished that allow adjustment for the amount of incipient decay if the use requires separation of incipient and typical decay. Both Kimmey (1956) and Laurent (unpublished data) found that there were few reliable external indicators of cull in southeast Alaska.

[1]For our purposes forest disease will be described as impairment, in whole or in part, of the health of trees caused by living organisms (other than insects) or by chemical or physical factors in the environment.

SITKA SPRUCE

The first interest in decay of southeastern Alaska timber was generated by the use of Sitka spruce for aircraft construction during World War I. Sitka spruce was cut both in southeast Alaska (Thorne Bay) and in British Columbia and shipped to England for aircraft construction. The long time in transit and in storage yards gave incipient decays already in the timbers a chance to develop at an accelerated rate. At the same time sound timbers were exposed to infection by stain and decay fungi due to poor storage conditions in dock and lumber yards. The immediate result was a series of studies and publications which dealt mainly with the significance of discolorations in wood for aircraft and with the strength properties of the wood in the early incipient stages of decay (Boyce 1923, Cartwright 1930, Colley 1921). With the onset of World War 11, the same cycle was initiated and resulted in similar studies with the main difference being one "on the ground study" in southeast Alaska (Anonymous 1942, Baxter and Varner 1942, Englerth 1947, Englerth and Hansbrough 1945, Scheffer et al. 1941).

From the turn of the century on as Sitka spruce was being widely planted in Europe, considerable knowledge was gained about diseases. The extent of this work, particularly in root diseases, is reflected in the titles listed by Harris and Ruth (1970).

A study by Bier et al. (1946) found Sitka spruce in the Queen Charlotte Islands subject to decay by fungi more commonly found attacking timber in service. The two fungi, *Trametes serialis* Fr. and *Poria monticola* Murr., were responsible for 8.42 percent of the total infections and were second in importance among the brown trunk rots.

This study reported *Fomes pinicola* (Swartz ex Fr.) Cke. the most frequent brown trunk rot and responsible for 13.9 percent of the total infection. This was in contrast to the usual situation in the coniferous forests of western Canada and the United States where *F. pinicola* is considered a rotter of dead material and of minor importance in the decay of living trees.

Root and butt rots were responsible for 27.3 percent of the infections with *Polyporus schweinitzii* Fr. (15.0 percent) and the *Poria subacida* (Pk.) (7.3 percent) causing most of this decay. In three instances *P. schweinitzii* was found causing extensive decay in the upper portions of trees independent of any basal infection.

Brown pocket heart rot, caused by *Lentinus kauffmanii* A. H. Smith was not found to be serious in any locality and caused only 6.4 percent of the infections. This was contrary to the previous belief that it occurred abundantly in local areas.

Sap rots were uncommon, occurring only on dead wood associated with scars.

The greatest volume losses were caused by *Fomes pini* (Thore ex Fr.) Karst., *F. pinicola*, and *Polyporus schweinitzii*. The loss ranged from 4.6 percent of gross merchantable volume for *F. pini* to 1.5 percent for *P. schweinitzii*. A major portion of the loss in grade 1 logs was due to *P. schweinitzii*, while *F. pinicola* caused the greatest loss in grade 3 logs. Over half the rot occurred in the upper part of trunks which would have yielded grade 3 logs anyway.

A relationship between age and decay was indicated, with little decay found in trees under 200 years old.

As an outgrowth of a request from the Alaska Spruce Log Program, Englerth (1947) spent part of 1942 and 1943 in southeast Alaska. The objective of the work was to develop techniques to aid cruisers, fellers, and buckers in the recognition and evaluation of decay in trees and logs. Felled and bucked spruce from 12 locations on the Tongass National Forest were examined. The data were supplemented with observations of standing timber on other locations and by examination of Alaskan spruce logs being processed in Washington mills. Of the 630 trees examined, 183 were infected by decay organisms. There were 213 decay columns in the 183 trees, with some trees infected by two or more species of fungi. Half of the infections originated in the roots. Twelve fungi were responsible for most of the decay. *Polyporus schweinitzii* and *P. borealis* Fr. were the most destructive of the 12 fungi. Being root and butt rotters, these species destroyed high-value material in the first log. Conks were seldom produced by any of the fungi; and the presence of decay could only be estimated by frost cracks, broken tops, cankers, and other visible injuries.

Kimmey (1956) examined 232 Sitka spruce and found that white rots caused 16 percent and brown rots 84 percent of the cull. *Fomes pini*, *Armillaria mellea* (Vahl ex Fr.) Quél., and *F. annosus* (Fr.) Cke. were the main white rot organisms causing 8.6, 4.4, and 1.1 percent of the total cull. The brown rot fungi: *F. pinicola*, *Polyporus schweinitzii*, and *P. sulphureus* (Bull.) Fr. caused 73.3, 4.3, and 3.8 percent, respectively, of the total cull. No differences in cull percent were noted for altitude or for geographical location in southeast Alaska.

WESTERN HEMLOCK

Since World War I, western hemlock has slowly changed from a disfavored weed species to a species valued for both pulp and lumber, and a need for knowledge of its decays developed. The increased utilization of western hemlock is reflected in the increase of publications concerning its decays. The concern over hemlock diseases is shown by the number of publications on the subject listed in Walters' (1963) bibliography of western hemlock.

Weir and Hubert (1918) mistakenly attributed practically all decay of western hemlock in the Northwest to *Echinodontium tinctorium* Ellis and Everh. Branch stubs were thought to be the main infection court for this fungus. Southwestern slope sites were stated to be less and river bottom sites more conducive to decay. Rigid sanitation measures were recommended for timber sales--particularly that all infected cull material should be destroyed by fire.

Beginning in 1935 Englerth (1942) dissected and analyzed 801 western hemlocks in western Oregon and Washington. The results were quite different from Weir and Hubert's earlier work which had been done in northern Idaho outside the optimum range of the species. *Fomes annosus* caused 21.0 percent of the board-foot decay, *F. pini* 19.2 percent, *F. applanatus* (Pers.) Gill. 17.1 percent, *F. robustus* 10.1 percent, *Ganoderma oregonense* Murr. 7.2 percent, *F. pinicola* 6.7 percent, and *Echinodontium tinctorium* only 5.3 percent. The greatest number of infections occurred in falling tree scars, while infections entering through mistletoe knots accounted for the greatest amount of decay. *F. pini* and *F. robustus* were more frequently found in the Cascades, while F. *annosus* and *F. applanatus* were more comon in the coast areas.

In 1949 Buckland et al. (1949) published the results of a study of decay in western hemlock and amabilis fir in the Franklin River area of British Columbia. They found that *Poria subacida*, *Fomes annosus*, *Armillaria mellea*, and *Polyporus sulphureus* were the main causes of root and butt decays in western hemlock. *F. pinicola*, *F. pini*, *Stereum abietinum* Pers., *F. robustus*, and *Hydnum* spp. were the major trunk decay organisms. Net periodic increment never became a negative quantity, and the average net volume gained continually. No difference in decay was found between slow- and fast-growing trees.

Fomes pini was the only fungus that usually produced conks or other external indications of decay. Since *F. pini* caused only 12.8 percent of the decay, decay could be accurately estimated only by careful examination of a large sample of felled trees.

In the Queen Charlotte Islands, Foster and Foster (1951) found total decay loss (including dead trees) in western hemlock to be 25.5 percent of the gross volume. There were relatively minor losses from heart rot in trees with less than 40-inch d.b.h. (no dead trees included). Individual trees are nonproductive after 500 years of age. In the understory there was a substantial volume of pulpwood (29.5 cords per acre) with little decay loss in trees under 14-inch d.b.h. No single fungus was responsible for a loss of more than 2.0 percent of gross volume. Twenty-seven fungi, exclusive of those confined to slash or other dead material, were isolated. Fifteen of the isolated species were relatively important heart rotters. The four most important decay fungi were: *Fomes pinicola* 1.6 percent, *F. pini* 1.4 percent, *F. annosus* 1.2 percent, and *Polyporus sulphureus* 1.0 percent of the gross volume. As was true of Sitka spruce in this area (Bier et al. 1946), 50 percent of the total decay was confined to the lower grades of timber (pulpwood material). There was considerable variation in cull, ranging from 15 to 45 percent depending on location. The Indian paint fungus, *Echinodontium tinctorium*, was not present.

Klein (1951) found a correlation between site, size, and decay for western hemlock in southeast Alaska. There was less defect on better sites, and the largest trees on any site were the most defective.

An examination of 230 western hemlock in southeast Alaska by Kimmey (1956) showed no differences in cull due to altitudinal or geographical location.

Brown rots caused 38 percent and white rots 62 percent of the cull, a reverse of the situation in Sitka spruce.

Armillaria mellea, *Fomes annosus*, and *Pholiota adiposa* (Fr.) Quél. were the main white rotters causing 25.9, 20.5, and 9.0 percent of the total cull. The main brown rot fungi were *F. pinicola*, *Polyporus sulphureus*, and *P. schweinitzii* causing 22.2, 6.2, and 5.2 percent of the total cull.

Foster et al. (1958) conducted a study in western hemlock in the Kittimat Region of British Columbia. Dead hemlock accounted for 13 percent of the total hemlock volume. Dead trees, on the average, contained only 19 percent of their gross volume in sound wood. The decay loss in living hemlock averaged 31 percent of gross volume. The major decay fungi were: *Fomes pini* causing 24.1 percent of the infections and 47.9 percent of the decay, and *Echinodontium tinctorium* with 17.5 percent of the infections and 19.8 percent of the decay. One decay fungus, *Poria tsugina* (Murr.) Sacc. & Trott, gained entrance to the stem mainly through mistletoe infections. Most decay occurred in the upper half of trees, but occasionally there were substantial losses in the butt log due to basal scar infections and downward extensions of trunk rots. Most decay was hidden defect, and it was not possible to differentiate between moderate and highly defective trees before felling even if conks were present. Approximately 27 percent of the trees were scarred, and over 70 percent of these were in the first 16 feet of the bole. Less than 10 percent of the total infections resulted from root-rotting fungi.

Childs[2] found *Armillaria mellea* causing "greater than normal" mortality in a pole stand of western hemlock. The fungus attacks appeared to be cyclic and associated with drought years.

In 1971 Miller[3] conducted a disease survey of young-growth stands. *A. mellea* was frequently found on the roots of windthrown trees but did not appear to be doing a great deal of damage. The young stands appear to be free of damage due to heart rot fungi at present.

There is an apparent east-to-west (interior-to-coast) and south-to-north change in fungus, host, and amounts of cull caused by various fungi (Buckland 1946, Englerth 1942, Foster et al. 1958, Kimmey 1956, 1965). Variation in cull and fungi responsible holds not only among geographic regions but is also true of rather restricted local areas (Englerth 1942). *Echinodontium tinetorim*, the Indian paint fungus, and *Fomes pinicola*, and *F. pini* serve as good examples of regional variation. *E. tinctorium* causes severe damage to hemlock in northern Idaho and the upper Columbia region of British Columbia (Foster et al. 1954, Weir and Hubert 1918), moderate damage in the Cascade Range (Foster et al. 1958), little damage in western Oregon and Washington and the coastal region of British Columbia, and none in southeast Alaska. The fungus has been reported from Vancouver Island[4] but nowhere else in the islands of British Columbia or southeastern Alaska. *E. tinetorim* has, however, been reported from Alaska in mountain hemlock on the Chugach National Forest (Ellis 1895). *F. pinicola* is the major cause of decay in southeast Alaska (Kimmey 1956). In other areas *F. pinicola* is considered a scavenger fungus (Englerth 1942) and not a major cause of decay in living trees.

Fomes pini, cause of the most common heart rot of Sitka spruce and western hemlock in the Pacific Northwest States and British Columbia, is of less importance in southeast Alaska. Cull resulting from this fungus lessens northward and westward and switches over to mountain hemlock which suggests an altitudinal effect.

Fomes annosus and *Armillaria mellea*, root rotters, are a threat to new stands which are coming in on old clearcuts. These two fungi cause loss by direct killing of reproduction, by weakening root systems thereby subjecting

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[2]T. W. Childs. Diseased hemlocks at Edna Bay, South Tongass N.F. 1962 unpublished report on file at Pacific Northwest Forest & Range Experiment Station, Portland, Oreg.

[3]D. R. Miller. An extensive forest disease survey of second-growth stands in southeast Alaska. Unpublished report on file at U.S. Forest Service, Region 10, Juneau, Alaska.

[4]Personal communication with J. A. Baranyay, Pacific Forest Research Centre, Canadian Forestry Service, Department of the Environment, Victoria, B.C.

the trees to windthrow and insect attack, by reduction of growth, and through loss of sound wood. Even where stands appear perfectly healthy, there are probably fairly sizable losses due to growth reduction.

Of the two, *A. mellea* is probably doing the most damage to western hemlock in southeast Alaska at the present time (Kimmey 1956). This fungus is present throughout the area; and although it attacks all commercial species, it is most severe in western hemlock. It normally is more frequent on dry sites or on better sites during dry years (Boyce 1961, Thomas 1934). Damage is most severe after drought years and on soils no more than weakly acid. Trees weakened by insects, other fungi, drought, or any other means are very susceptible to attack by *A. mellea*. The fungus is widespread as a saprophyte which in some instances masks the primary causes of reduced tree vigor. In cases of this nature, damage attributed to *A. mellea* tends to be overestimated. The problem of determining exactly the annual loss from reduced growth and death is complicated by variation in severity of damage by locality, host, site, and year (Leaphart 1963). Childs (see footnote 2) found the fungus definitely parasitic and causing abnormal damage to reproduction at Edna Bay on Kosciusko Island.

Fomes annosus like *A. mellea* is a serious pathogen on western hemlock but is of minor importance on Sitka spruce and the two cedars. In western Oregon and Washington *Fomes* root rot was the most important decay fungus in western hemlock and in southeast Alaska, the second most important (Englerth 1942, Kimmey 1964). The fungus is not confined to the root system and is commonly a wound pathogen (Rhoades and Wright 1946). In partially cut stands in British Columbia and the Pacific Northwest, *F. anmsus* was the most damaging fungus found in logging wounds (Shea 1960, Wallis et al. 1971, Wright and Isaac 1956). Western hemlock stumps are readily infected, and a high incidence of stump infection has been reported following thinning in young stands (Driver and Wood 1968, Hodges et al. 1970). Infected stumps serve as a source of spore inoculum and may help spread the organism through stump-to-tree contact.

WESTERN REDCEDAR AND ALASKA-CEDAR

Buckland (1946) found 77 species of basidiomycetes on living and dead western redcedar in British Columbia. A total of 725 trees in 19 locations were examined, 615 in the coastal forests and 110 in the interior. The same four principal species of wood-destroying fungi were present in both the coast and interior areas but in a slightly different order of importance (expressed in percentages of total infections). On the coast these were in order of importance: *Poria asiatica* (Pilát) Overh. (*P. sericemolis* Rom.), *P. albipellucida*, *Fomes pini*, and *P. weirii*. The order in the interior was: *P. asiatica*, *P. weirii*, *F. pini*, and *P. albipellucida*. Many infections were multiple with mixtures of two or more of the four major pathogens, No reliable method was found for predicting the amount of decay. One reason is almost complete absence of conks on trees. Fire scars and other basal wounds were the major indicators and entrance courts for over 90 percent of old infections. At no time during the 450 years of growth covered by Buckland's study did loss by decay equal or exceed growth (mortality not considered). Young vigorous trees were as susceptible to infection by major decay fungi as the overmature trees were; however decay impact was greater in the overmature class.

In a southeast Alaska study, Klein (1951) found that cedar was about twice as defective as hemlock and 20 times as defective as spruce in diameters to 35 inches.

Kimmey (1956) found that two white rot fungi, *Poria albipellucida* Baxter and *P. weirii* (Murr.) Murr. caused 44.6 and 40.6 percent of the total cull. Unidentified white rot and brown rot fungi caused 9.9 and 2.0 percent of the total cedar cull.

Alaska-cedar forms such a small component in the Alaskan stands (5 percent) that both Klein (1951) and Kimmey (1956) lumped it with redcedar.

Klein (1951) reported the cedars to be twice as defective as hemlock and 20 times as defective as spruce in diameters to 35 inches.

Two fungi, *Poria albipellucida* and *P. weirii,* caused 85 percent of the cedar volume loss reported in Kimmey's (1956) study.

Andersen (1959) reported *Armillaria mellea* on dead and dying Alaska-cedar, attributing the fungal attack to unfavorable moisture conditions. At the same time the thin bark and resulting susceptibility to mechanical injury of the species were pointed out.

The lack of howledge concerning the pathology of Alaska-cedar is not restricted to southeast Alaska but extends throughout the range of the species. In British Columbia Eades (1932) described the wood and mentioned its durability but said nothing about specific disease. Shaw and Harris (1960) (Shaw 1958, 1973) lists and describes diseases and decays of trees native to Washington State and again there is little concerning Alaska-cedar.

Both red- and Alaska-cedar are high value woods and are attracting increasing attention. The 4 billion board feet of each species present in southeast Alaska (Hutchison 1968) require a more thorough understanding of their pathology for proper management.

DWARF MISTLETOE

Many stands of western hemlock in southeast Alaska are severely infested by dwarf mistletoe, *Arceuthobium tsugense* (Rosendahl) G. N. Jones (fig. 1). This mistletoe is a dioecious seed-bearing plant having an endophytic system which invades the cortex and xylem of its host, The plant flowers from spring to fall, reaching a maximum during August and September. Seed dissemination is generally the following September to November (Smith 1969, 1971). When ripe, the seeds are forceably ejected, sometimes for considerable distance; but the majority fall within 20 feet (Smith 1966). For infection to occur, the seed, with its sticky coating, must land on bark not more than 5 years old (Hawksworth and Wiens 1972).

Dwarf mistletoe reduces the vigor and growth rate of the western hemlock. The trees are deformed by burls and witches brooms, made susceptible to insects and other diseases, and killed (Foster and Wallis 1969, Gill 1935, Hawksworth and Wiens 1972, Smith 1966, Weir 1916, Wellwood 1956). The large burls, caused by trunk infections, deform and weaken the trunk so that the wood is of lower value or worthless. Trunk infections are particularly abundant and damaging (Wellwood 1956).

There are naturally occurring parasites of dwarf mistletoe, but it is not possible to use them for control at this time. The only feasible controls are

Figure 1.—*Arceuthobium tsugense* on western hemlock in southeastern Alaska.

silvicultural. A clearcut (in the absolute definition of the term) is the easiest and most sure method of control. Other methods such as removing infected trees and pruning infected branches will probably be too costly in southeast Alaska./

For infected stands of advanced young growth, the most practical means of control is to maintain a tight canopy. Mistletoe responds to light quite rapidly and openings in the stand will accentuate the problem.

In stands where a dense canopy has been maintained, infected trees will suffer from competition to a greater degree than their uninfected neighbors and will tend to remain static or drop out of the stand. Shea (1966) found that in 80-year-old infected stands of western hemlock severely infected trees appeared to have been overtopped by their neighbors and had died. Brooms and infected limbs died or failed to grow to large size under dense canopies.

Western hemlock is the only tree species seriously attacked by dwarf mistletoe in southeast Alaska. Sitka spruce, in two instances, has been found parasitized by the plant (Laurent 1966). The only occurrence reported on mountain hemlock was by Weir in 1913 (Hawksworth and Wiens 1972). Baxter (1952) has pictures of dwarf mistletoe on western hemlock. The location given is the Chugach National Forest. This location is probably in error and is on the Tongass National Forest. The Chugach National Forest encompasses the Prince William Sound and Kenai areas and is several hundred miles north of southeast Alaska.

OTHER DISEASES

There are many pathogens of southeast Alaska trees other than the decay fungi and dwarf mistletoe. The rust, needle cast, cankering, dieback, and staining fungi are enphytotic and normally do little damage.

In addition to biotic diseases there are abiotic diseases which weaken or kill the trees. Weather damage, such as early or late frost injury, freezing, winter drying, and drought, is the main cause of abiotic disease. Air pollution (such as the fume-killed trees in Silver Bay near Sitka) and salt damage normally play a very minor role here.

Sitka spruce is attacked by seven rust fungi not all of which have been reported from Alaska (Hepting 1971, Ziller 1954, 1959). Of the known rusts here the two cone rusts (*Chrysomyxa monesis* Ziller and *C. pyrolata* Wint.) and a needle rust (*C. ledicola* Lagh.) are most commonly encountered.

Chrysomyxa ledicola Lagh., which causes a rust on current year's needles, is very conspicuous at times. The orange-yellow aecia of the fungus give severely infected trees a yellowish color. The rust is heteroecius with the alternate host being Labrador-tea (*Ledum* sp.). Due to the growth habits of the alternate host, the rust is usually common near muskegs. Little damage is done by the rust unless there are several successive years of severe infection.

Uraecium holwayi Arth,, a needle rust, causes defoliation of both mountain and western hemlock. This rust attacks current year's needles and its alternate stage is unknown. Another needle rust of hemlock (*Melampsora epitea* Thum, f. sp. Ziller) with its alternate stage on willows occurs in British Columbia (Ziller 1954) but has not been reported in Alaska.

Alaska-cedar is subject to infection by *Gymnosporangium nootkatense* (Trel.) Arth., a needle rust (Arthur 1934). No alternate host is known.

Several needle cast fungi are found on Sitka spruce but only one, *Lophodermium piceae* (Fuckel) von Hohnel which occurs on old senescent needles, is common in southeast Alaska (Darker 1932). These hypodermataceous fungi either do not attack or are very uncommon on the other commercial tree species.

Western redcedar is attacked by *Didymascella thujina* (Durand) Maire which causes cedar leaf blight. This disease primarily attacks seedlings and saplings but can retard the growth of--and kill--trees of all ages (Anonymous 1967, Foster and Wallis 1969). High humidity and stagnant air such as is found in dense stands or under late spring snow cover promote the disease (Boyce 1961).

Control is not practical in the forest, but several applications of Bordeaux mixture during the summer will control *D. thujina* in ornamentals and nurseries (Anonymous 1967, Boyce 1961).

A conspicuous "flagging" is noted at times on western redcedar. This flagging is not a disease but a normal condition, It is characterized by isolated branchlets bearing reddish, dying, or dead foliage and occurs toward the end of the growing season.

Both spruce and hemlock are subject to canker diseases of varying severity. Normally the fungi causing these diseases are weak parasites which attack trees under environmental or other stress (Bier 1959, Foster and Wallis 1969, Funk 1963, 1964, 1965, 1966, Reid and Funk 1966). *Botrysphaeria picea* Funk, which causes perennial, swollen black cankers on living branches of spruce, and *Discocainia treleasei* (Sacc.) J. Reid & Funk, which causes fusiform swollen cankers on both spruce and hemlock, are the most commonly encountered. Childs (see footnote 2) attributed the cankering of hemlock at Edna Bay to weakly parasitic fungi which attacked drought-weakened trees.

A serious threat to hemlock regeneration and young growth is indicated by the extensive damage caused by *Sirococcus strobilinus* (Desm) Petrak at Thomas Bay and Edna Bay (Funk 1972; also see footnote 3) (fig. 2). Little is known of this disease or its potential in Alaska, but it has been damaging in Europe (Lagerberg 1933) and California.[5] It is enphytotic in southeast Alaska and normally had caused little damage. The fungus was first noticed on hemlock reproduction at Thomas Bay in 1967. Since the initial discovery, S. *strobilinus* appears to have become epiphytotic south of Frederick Sound (fig. 3). Why this has occurred is unknown. It may be tied in with silvicultural practices; and if this is so, the control techniques will probably depend on manipulation of these practices. As large continuous areas of reproduction are being created each year, the time factor for any control is getting short. If spread of the fungus is due to the silvicultural practice of clearcutting in large continuous areas (such as entire drainages) and to fertilizing some of these areas, we are probably creating large reservoirs of inoculum. It may be that we created the situation and are making it worse.

[5]Personal communication with R. S. Smith, Jr., Plant Pathologist, USDA Forest Service, Pacific Southwest Forest & Range Experiment Station, Berkeley, California.

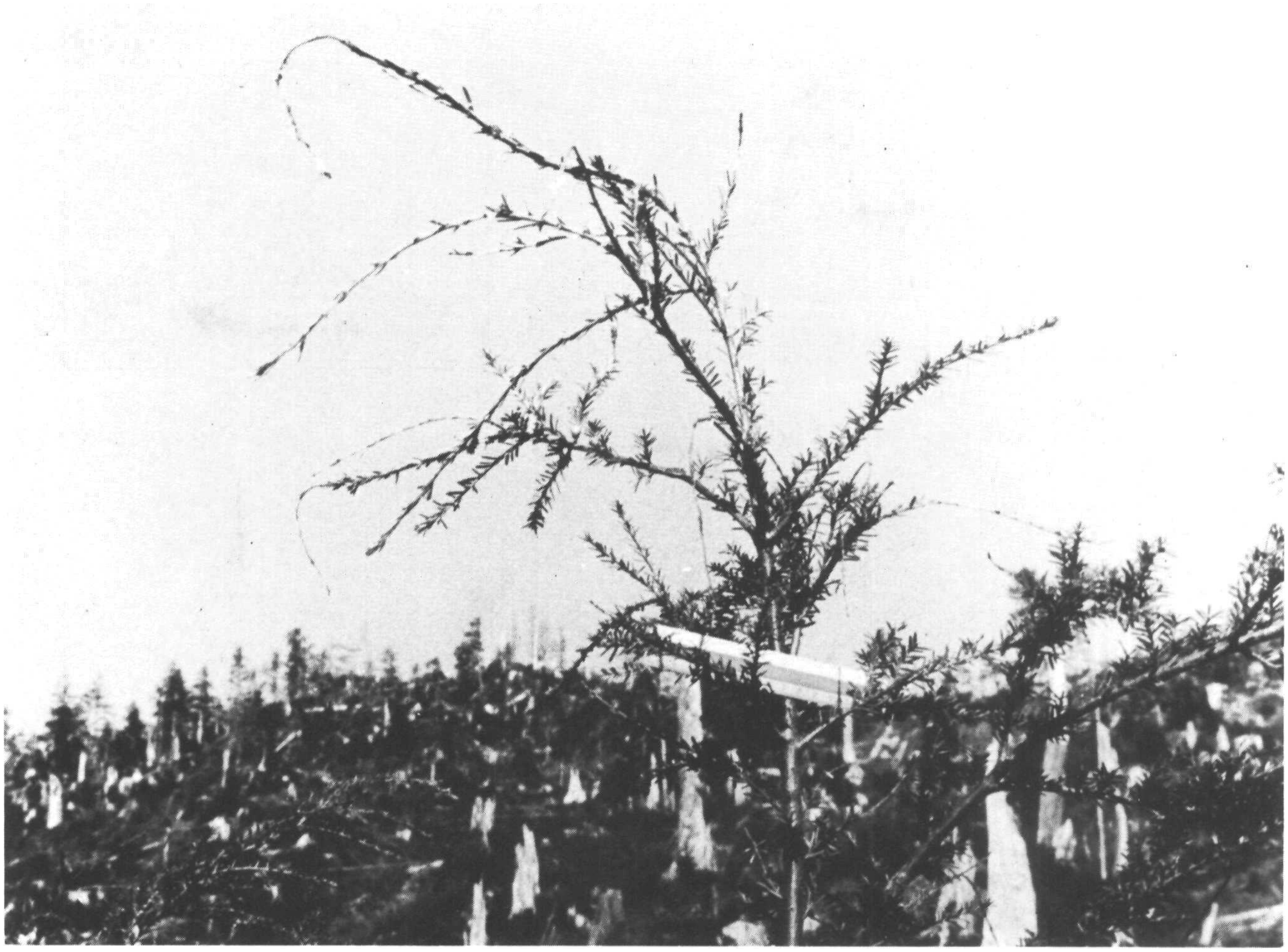

Figure 2.—Western hemlock sapling infected by *Sirococcus strobilinus.*

OTHER

Southeast Alaska stands are subject to periodic catastrophies of two types: windthrow and insect kill. Of the two, windthrow is the more common. Windstorms such as the Thanksgiving Day storm of 1968 uproot or breakdown millions of board feet of timber. A large part of this timber is salvable within certain time limits. At present, the timber managers must extrapolate these limits from studies made in other regions (Boyce 1929, Buckanan 1940, Buchanan and Englerth 1940, Childs and Clark 1953). On the Olympic Peninsula, blue stain has started in Sitka spruce and western hemlock 7 months after blowdown, decay in 2 years, and after 15 years the trees are no longer merchantable (Buchanan and Englerth 1940). Western redcedar sapwood is unmerchantable after 15 years.

Standing insect-killed western hemlock in western Washington and southern Vancouver Island deteriorated faster than those on the ground and, after 7 years, were unmerchantable (Engelhardt 1957, Shea 1956).

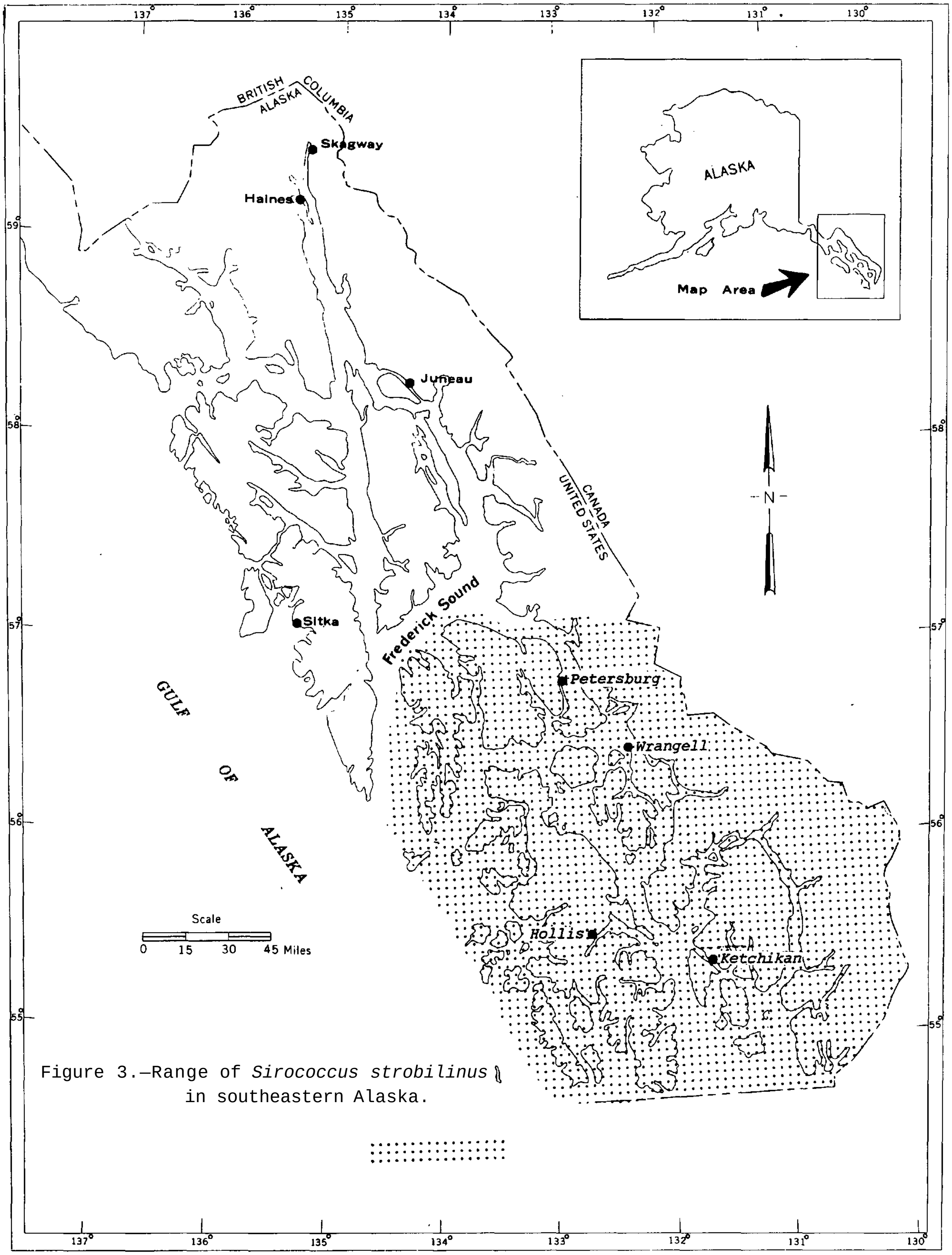

Figure 3.—Range of *Sirococcus strobilinus* in southeastern Alaska.

ECONOMIC AND MANAGEMENT CONSIDERATIONS

Death or decay of merchantable trees usually causes more concern than that of reproduction as it represents a loss of presently realizable value; but as time goes on and we turn to younger stands, reduction in growth rate and regeneration will become more and more important. In the long run, loss caused by slow acting chronic diseases probably exceeds loss due to sudden spectacular outbreaks.

It is to these chronic diseases in the young stands that we should direct the major portion of our attention. These diseases are being taken care of in old-growth stands by cutting, although most cutting has been in the younger, fast growing, old growth rather *than* the more decadent stands. This younger, fast growing, old growth is usually even- rather than all-aged.

Heart rots (top, trunk, and butt rots) are of more immediate concern to the timber operator than root rots as the volume loss is from the harvested portion of the tree. The value of lost material is emphasized by the fact that practically all disease studies in Alaska (Baxter and Varner 1942, Englerth 1947, Kimmey 1956, Kimmey and Stevenson 1957) have been cull or cull-related studies.

Root rots will become of prime importance as present stands are converted to young growth, Although some root rots cause decay in merchantable portions of trees and some are killers, they are principally reducers of vigor and growth rate, hence their importance in management of young-growth stands. In the instance of root rot fungi, such as *Fomes anmsus* or *Armillaria mellea*, infected old-growth stands should be cut early both to reduce the loss to decay and to remove stands no longer windfirm.

Dwarf mistletoe, which is present throughout most of southeast Alaska, will be of importance in management of hemlock stands. If this parasite is not kept out of newly regenerated stands, or at least kept to a low level, excessive losses will have occurred by maturity. Control costs will have to be carefully weighed against the value of the timber. Due to the island and rough topographic nature of southeast Alaska, transportation and housing will often be the limiting factors in control cost calculations.

In old growth, cutting should be in the more decadent stands as it is in these stands that we presently have our greatest losses. Cutting these stands first removes the material in which your greatest loss is occurring and makes the land available for new, vigorous young growth.

Air pollution first appeared as a problem in southeast Alaska with development of gold mining on Douglas Island, Sulfide and chloride fumes produced in the gold recovery process killed trees on several hundred acres. With closure of the last mine in 1924, the air pollution was eliminated and affected areas have restocked to forest cover.

With completion of the Ketchikan pulpmill in 1954 and the Sitka pulpmill in 1959, air pollution again became a problem. Sulfur oxide emissions from the mills have injured and killed Sitka spruce, western hemlock, western redcedar, and Alaska-cedar. In the case of the Sitka pulpmill the trees on approximately 400 acres have been killed, A proposed iron ore processing plant at Klukwan and potential plants at other ore deposits such as Port Snettisham, Union Bay, and Kasaan Peninsula could cause similar air pollution problems. However, in every case, equipment is available which can hold emissions to nontoxic levels.

RESEARCH DIRECTIONS AND PRIORITIES

In undisturbed forests, native diseases rarely become epiphytotic; the organisms are essentially in biological balance with their hosts. This was the situation here in southeast Alaska until the early 1950's, with the advent of the pulpmills and widespread cutting. Coinciding with the increase in cutting, there was a population increase coupled with better transport connections to the "Outside." The result of all the activity is and will be more "disturbed" forest area. It is in these areas of use, cuttings, roads, and campgrounds that we may look for upsets in the natural biological balance which lead to epiphytotic conditions. It is to these areas--the timber sales, roads, heavily used campgrounds, and trails--that we must direct our attention.

Disease is always present in the forest, and this disease may directly or indirectly affect the use for which the forest is managed. Type of use and degree of management will affect the incidence and importance of forest diseases, further complicating the forest manager's job. Land use may determine the degree of loss and the control measures which can be used and at the same time determine the direction in which research will be concentrated.

Due to the nature of the problem no clear division exists between disease research and disease survey. At the present level of the art in Alaska, both efforts need to be closely integrated.

Research should be in three directions, damage, control, and basic studies. It is impossible to clearly separate these studies, and in actual practice some of all three will be occurring at the same time although at any one time the major emphasis will be in a single direction.

Basic studies are more closely related to control than to damage. They are concerned (in the case of parasitic organisms) with the life cycles of pathogens, their interactions with their hosts, and the environmental conditions which promote or hinder the host-pathogen interrelationship. This is a search for the weak link in the chain and for the spot at which to attack the pathogen. It is to this "weak link" in the life cycle of the pathogen that the control studies are directed.

Disease control studies are a search for methods, adaptation of these methods, and determination of the practicability of the methods for the forest managers' use. Under the present extensive conditions of management (which is essentially timber sale management), silvicultural practices will probably be the most practical direction for control studies.

A clear howledge of overall disease impact in southeast Alaska is needed. Before realistic control programs can be initiated, knowledge of what, where, how much, and what will happen if we do this is absolutely essential.

The susceptibility of the timber stands to windthrow and insect attack makes damage studies of great use. These studies are of the mode, rate, and severity of damage to the trees and stands under various infection rates and environmental conditions. Knowledge of rate of deterioration of dead material such as windthrow, standing insect-killed timber, and standing disease-killed timber would greatly reinforce forest management practices and interpretation of results of disease surveys. Detection and survey methods suitable to timber values, terrain, and climate will have to be developed for southeast Alaska.

The disease problems of old growth are largely being taken care of by cutting. This same cutting is rapidly converting large areas of old growth to reproduction and young growth. It is in these areas of young growth that our disease problems will most probably arise. With a few exceptions the reproduction and young-growth stands appear quite healthy at this time with the diseases that are present just doing a bit of natural thinning. These new stands should be closely studied. Damage appearing in young stands may be due to--or may be corrected by--certain silvicultural practices such as thinning, or perhaps completely prevented by a modification of the methods used in removing the previous stand.

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P.O. Box 3141
Portland, Oregon 97208

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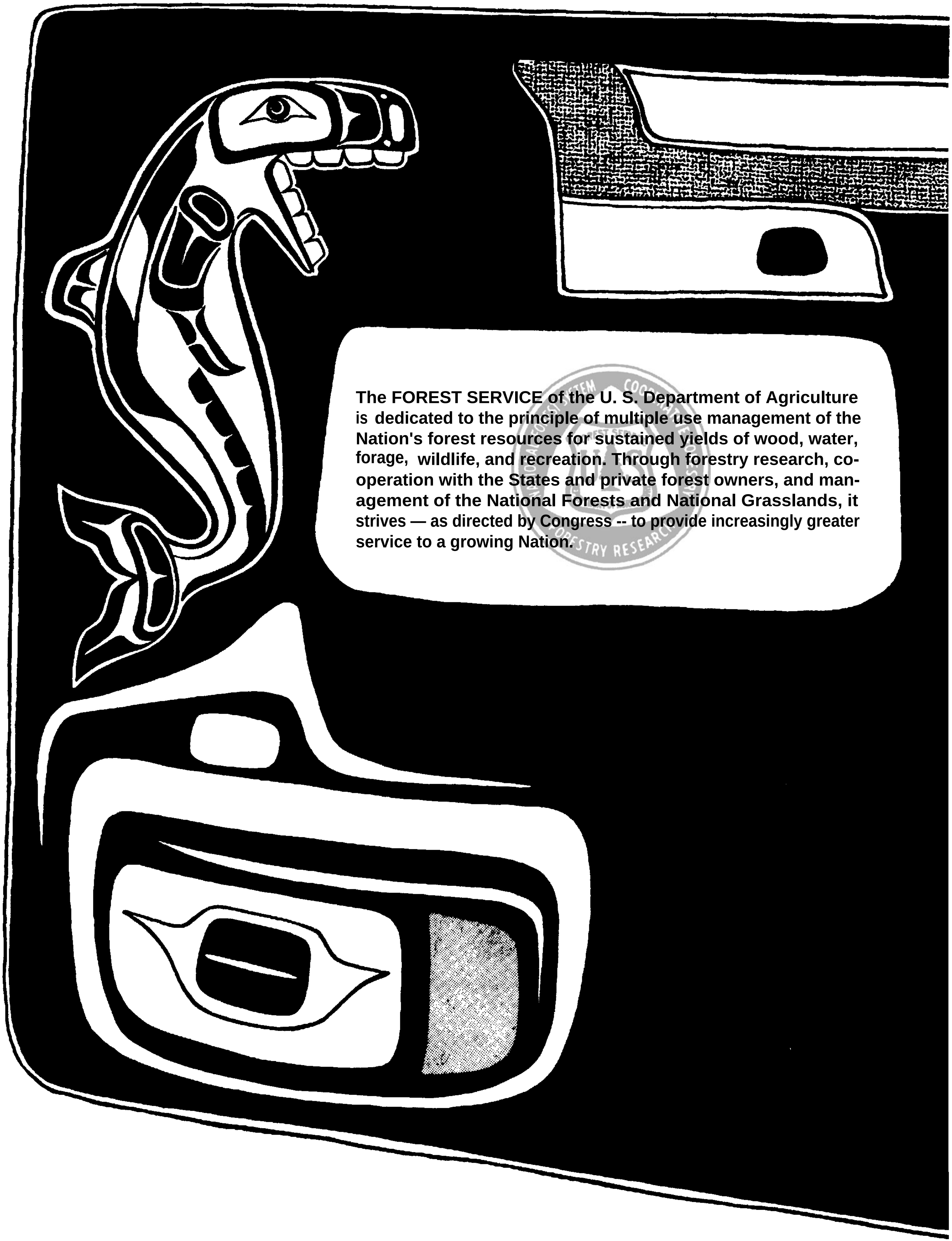

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