WORLDWIDE INTRODUCTION AND ESTABLISHMENT OF BARK AND TIMBER BEETLES (COLEOPTERA: SCOLYTIDAE AND PLATYPODIDAE)

by

Kenneth Richard Marchant

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Name: Kenneth Richard Marchant

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Examining Committee:

Chairman: Dr. B. P. Beirne

Dr. J.H. Borden
Senior Supervisor

Dr. J. E. Rahe

Mr. J. W. Gold

Dr. R. W. Mathewes
External Examiner

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Author:

(signature)

KENNETH RICHARD MARCHANT

(name)

25 March 76

(date)

ABSTRACT

The current world situation with regard to introduction and establishment of bark and timber beetles (Coleoptera: Scolytidae and Platypodidae) was examined by means of an extensive literature review, examination of various plant protection legislation, and through personal communication with world experts. Fifty-four species of scolytids and 3 platypodids are listed as being established outside their native ranges, due primarily to ineffective quarantine procedures.

The most important biological, biogeographical and ecological factors affecting establishment are: opportunity, degree of pre-adaptation, adaptability, and the presence of susceptible host material of suitable size and age for beetle development. Analysis of these factors as well as past establishment records and lists of intercepted beetles compiled from various plant protection records led to the selection of 16 scolytids demonstrating particular potential for future exotic pest status.

Plant protection legislation and policies of all major wood-producing countries were examined and concluded to be relatively effective in developed timber-producing countries for the following reasons: adequate finances alloted for maintenance of sufficient, well-trained and efficient personnel; willingness to accept a minor degree of inefficiency in handling; and, a willingness and ability to enforce legislation. Adequate legislation and policies were conspicuous by their absence in many tropical countries where the threat posed by establishment of exotic bark and timber beetles is perhaps the greatest.

ACKNOWLEDGEMENT

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INTRODUCTION

Many exotic bark and timber beetles have become established in the various timber-producing countries of the world causing widespread destruction and forcing the re-evaluation of current plant protection legislation and practices. Yet, many countries do not recognize the threat posed to their forests or those of neighbouring countries, by these and other potential exotic bark and timber beetle pests. As a result, several important introductions have taken place in recent years and more will undoubtedly take place in the future.

My objectives were:

1) to survey the past worldwide introductions and interceptions of scolytids and platypodids;
2) to analyze the biological, economic, geographic and legal factors that influence introductions of exotic bark and timber beetles; and
3) to identify selected species which represent major threats of future introduction and significant economic impact.

Information was obtained primarily through examination of the published literature, and correspondence with plant protection agencies in timber producing and exporting countries.

SURVEY OF INTRODUCTION AND INTERCEPTIONS

In this paper, the term introduction implies that man is responsible for members of a species entering a new geographical area. An established species is one that has extended its range, either naturally or through introduction by man, and which has been able to reproduce through infesting fresh host material in a new region. Table I lists 54 and 3 species of scolytids and platypodids, respectively, which have become established outside their natural geographic ranges. Some species in which the mode of introduction is unknown are listed, despite the possibility that establishment may represent a natural extension of geographic range.

An interception is the capture by man of one or more individuals of a given species in the act of being introduced. Interception records of scolytids and platypodids by 8 countries are documented in Table II. These records vary greatly between countries depending on their plant protection legislation and the manner in which it is implemented. Moreover, these records do not document introductions which do not result in establishment, since such events usually go unnoticed.

Table I. Scolytidae and Platypodidae established outside their normal geographic ranges

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
SCOLYTIDAE					
Blastophagus minor Hartig =*Myelophilus minor* =*Tomicus minor*	Palaearctic region excluding China	China	**Pinus halepensis* **P. nigra* *P. radiata* **P. sylvestris* **Abies* spp. **Picea* spp. †**Pinus* spp.	Unknown	Balachowsky(1949) Chararas(1962) Browne(1968) Rozhkov(1970)
Blastophagus piniperda L. =*Myelophilus piniperda* =*Tomicus piniperda*	Wide Palaearctic distribution	Japan (failed to become established in North America, 1934)	*Pseudotsuga menziesii* †*Pinus densiflora* †*P. koraiensis* †*P. pentaphylla* †*P. thunbergii* †**Pinus* spp. †**Picea* spp. †**Larix* spp.	Unknown	Chararas(1962) Nobuchi(1966,1972) Jones,T.(1967) Browne(1968) Milligan(1970)
Coccotrypes advena Blandford =*Poecilips advena* =*P. persicae* =*P. cubanus* =*Thamnurgides persicae* =*Dendrurgus philippinensis*	Indo-Malayan region	Most Pacific islands; northern South America; several of the Antilles; Cuba; Surinam	Many tropical trees	Via infested fruit	Wood(1966,1973) S.L.Wood[b](pers.comm.)
Coccotrypes dactyliperda Fabr.	Complete range unknown. Type locality from Germany. Species described after establishment there	Malaya; some regions of tropical America; Hawaii; New South Wales	*Phytolephus* spp. †*Persea gratissima* †*Phytolephus macrocarpa*	In nuts, vegetable buttons	Brimblecombe(1953) Browne(1961)
Coccotrypes indicus (Eggers) =*C. insularius* =*Poecilips indicus* =*P. eggersi* =*Xyleborus conspeciens* =*Thamnurgides indicus*	Indo-Malayan region	Northern South America; Central America; the Antilles; probably established in Florida (1975)	*Swietenia* spp. Many other species	Fruit & bark of mahogany etc.	Browne(1961) Wood(1973) S.L.Wood[b](pers.comm.)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Coccotrypes rhizophorae (Hopkins) =*Dendrurgus rhizophorae* =*Thamnurgides nephelii*	Indo-Malayan, & Indonesian area	Coast of southern Florida & adjacent islands. May occur throughout Caribbean	†*Rhizophora mangle*	In fruit	S.L.Wood[b] (pers.comm.)
Cryphalus wapleri Eichhoff	Australia	New Zealand, North Island (1946)	*Ficus carica* *Malasia* spp.	Unknown	Brimblecombe (1953) Milligan (1970) Kuschel (1972)
Dactylipalpus transversus Chapuis	Malaya; Andamans; Sumatra; Java; Borneo; Celebes; Philippines; North Queensland, Australia	New South Wales, Australia (probably temporary)	*Dyera costulata* *Pterocymbium* sp. *Mesua ferrea* *Hevea brasiliensis* *Tectona grandis* Many other species	Unknown	Browne (1961)
Dactylotrypes Uyttenboogaarti Eggers	Canary Islands	France; North America (from France, 1940). Present status unknown.	**Phoenix canariensis* †**Phoenix* spp.	Probably in palm seeds	Balachowsky (1949) Chararas (1962)
Dendroctonus micans Kugelann	Northeastern Europe & northern Asia	France (1952). Has spread naturally throughout Turkey	†**Picea orientalis* †**Picea* spp.	Probably in unbarked wood	Graham (1967) Jones, T. (1967) Acatay (1968) Browne (1968) P.Carle[c] (pers.comm.)
Gnathotrichus materiarius (Fitch)	Eastern North America	Netherlands (1965); Germany (1965); France (1933,1952); probably many separate introductions, some in 19th century	†**Abies* spp. †**Larix* spp. †**Picea* spp. †**Pinus* spp. †**Pseudotsuga menziesii* †**Tsuga* spp.	Dunnage wood, casewood, imported logs	Balachowsky (1949) Francke-Grosmann (1964) Doom (1967) Gauss (1968) Menier (1972) P.Carle[c] (pers.comm.) J. P.Vité[d] (pers.comm.)
Hylastes angustatus (Herbst)	Europe, Japan	Republic of South Africa; Swaziland	†*Pinus elliottii* †*P. montezumae* †*P. patula* **P. pinaster* **P. pseudostrobus* †*P. radiata* †*P. taeda*	Possibly in logs or dunnage	Hepburn (1964) Jones, T. (1967) Phillips (1967) Browne (1968) H.Geertsema[e] (pers.comm.)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Hylastes ater (Paykull)	Wide Palaearctic distribution, including Japan	Australia; New Zealand (1929)	**Pinus densiflora* **P. nigra* **P. pinaster* †*P. ponderosa* †*P. radiata* **P. sylvestris* †*Araucaria cunninghami* †*Pseudotsuga menziesii* **Thuja* spp.	Unknown	Brimblecombe(1953) Rawlings(1953) Zondag(1964) Browne(1968) Milligan(1970) Kuschel(1972) Bain(1974) F.D.Morgan[f](pers.comm.)
Hylastes attenuatus Erichson	Europe, including the U.K.	Japan (probably). (No record of introduction)	†*Pinus densiflora* †*P. pumila* †**Pinus* spp.	Possibly logs	Nobuchi(1966) Browne(1968)
Hylastes linearis Erichson	Europe	Republic of South Africa	†**Pinus* spp.	Unknown	Hepburn(1964) H.Geertsema[e](pers.comm.)
Hylastes opacus Erichson	Wide Palaearctic distribution, including Korea & Japan	Republic of South Africa	**Pinus densiflora* **P. sylvestris* †**Pinus* spp.	Unknown	Hepburn(1964) Browne(1968) Lee(1969)
Hylastes pinastri Eggers	Europe	Cape Province, Republic of South Africa	**Pinus canariensis* †*P. elliottii* †*P. montezumae* †**P. patula* †**P. pinaster* †*P. pseudostrobus* †*P. radiata*	Unknown	Hepburn(1964) H.Geertsema[e](pers.comm.)
Hylastinus obscurus (Marsham)	Europe, including the U.K.	North America (1878) Now widespread throughout continent	†**Medicago* spp. †**Melilotus* spp. **Ononis* spp. **Spartium* spp. †**Trifolium* spp. **Ulex* spp.	Probably in herbaceous plant roots	Balachowsky(1949) Chamberlin(1958) Elton(1958)
Hylesinus oleiperda Fabricius	Wide Palaearctic distribution	Argentina (no record of introduction)	†**Olea europea* **Fraxinus excelsior* **Syringa* spp.	Probably in imported nursery stock	Hepburn(1964) Browne(1968)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Hylurgus ligniperda (Fabricius)	Europe (Mediterranean area); Atlantic islands	Japan; South America; Republic of South Africa; New Zealand (1974), (from Australia); Australia (1942); Sri Lanka; Swaziland	†*Pinus densiflora* **P. pinaster* †*P. radiata* †**Pinus* spp.	Probably in dunnage & logs. Into New Zealand in pine timber dunnage	Brimblecombe(1953) Nobuchi(1960) Hepburn(1964) Browne(1968) Anonymous(1974) J.Bain[g](pers.comm.) H.Geertsema[e](pers.comm.) F.D.Morgan[f](pers.comm.)
Hypocryphalus mangiferae Stebbing	Orient	Barbados; Tanzania; Samoa; Sri Lanka; Ghana; Malaya; Pakistan; probably all mango growing areas	†**Mangifera indica*	Bark of dead or moribund branches	Browne(1961,1968)
Hypothenemus areccae Horn	Malaysia	Tropical America	†*Pinanga* sp.; & several other species	In bark	Browne(1961)
Ips calligraphus (Germar)	Eastern North America	California; the Philippines	**Pinus strobus* †**Pinus*	Logs, slash, bark	Browne(1968) Lindquist(1969) Bright&Stark(1973)
Ips cembrae (Heer)	Palaearctic, including Japan, Korea, & Taiwan	The U.K. (1946-1948)	**Abies* spp. †**Larix decidua* †**Larix* spp. †**Picea* spp. **Pinus* spp. †*Pseudotsuga menziesii*	Timber from Germany through ports in Scotland	Crooke&Bevan(1957) Bevan(1964) Jones,T.(1967) Browne(1968) D.Bevan[h](pers.comm.)
Ips grandicollis (Eichhoff)	Eastern North America	Australia (1943)	†*Pinus halepensis* †*P. nigra* †*P. pinaster* †*P. radiata* †**Pinus* spp.	Pine timber with bark	Brimblecombe(1953) Morgan(1967) Browne(1968)
Ips interstitialis Eichhoff	Central America; British Honduras; Jamaica	Philippines (1939-1945)	**Pinus caribaea* †*P. insularis* †**Pinus* spp.	Introduced accidentally by U.S. military	Browne(1968)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Ips sexdentatus (Boerner)	Wide Palaearctic distribution	The U.K. (1946-1948)	†**Pinus sylvestris* †**Pinus* spp.	From France & Germany in mine pitprops & other timber	Gosling (1949) Browne (1968) D.Bevan[h] (pers.comm.)
Leperisinus varius Fabricius =*L. fraxini*	Wide Palaearctic distribution	Brazil (status uncertain)	**Fraxinus excelsior* **Fagus* spp. **Juglans* spp. **Pyrus* spp. **Quercus* spp. **Syringa* spp.	Unknown	Balachowsky (1949) Browne (1968)
Orthotomicus caelatus Eichhoff	Eastern North America	Australia (status uncertain)	**Larix laricina* **Picea* spp. †**Pinus* spp.	Possibly in logs	Browne (1968) Milligan (1970)
Orthotomicus erosus Wollaston =*Onthotomicus erosus* =*Ips erosus*	Mediterranean area of Europe; France; North Africa	The U.K.	†**Pinus* spp.	Unknown	Balachowsky (1949) Browne (1968) Milligan (1970)
Phloeosinus cupressi Hopkins =*P. blackwelderi*	California	New Zealand (1943) Australia (1947) Panama	†**Chamaecyparis* spp. †*Cryptomeria* spp. **Cupressus* spp. **Libocedrus* spp. **Sequoia* spp. †**Thuja* spp.	Unknown	Brimblecombe (1953) Browne (1968) Milligan (1970) Wood (1971) Kuschel (1972)
Phloeosinus rudis Blandford	Japan	France	†**Thuja japonica* †*Thuja* spp. **Cryptomeria* spp.	*Thuja japonica* nursery stock	Balachowsky (1949) Chararas (1962) Nobuchi (1972)
Phloeosinus thujae (thuyae) Perris	Japan	The U.K.; France	†**Thuja japonica* †*Thuja* spp. †**Cupressus* spp. †**Juniperus* spp.	*Thuja japonica* nursery stock	Chararas (1962) White (1966) Welch (1968)
Phthorophloeus spinulosus Rey	Eastern Europe; Siberia; Scandinavia	France (1918)	†**Abies pectinata* †**Picea excelsa*	Unknown	Balachowsky (1949)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Pityokteines curvidens Germar	Europe, Orient	Republic of South Africa	**Abies pectinata* **Larix europea* **Picea* spp. †**Pinus* spp.	Unknown	Balachowsky(1949) Chararas(1962)
Polygraphus rufipennis Kirby	North America	Republic of South Africa (probably)	**Pinus strobus* †**Pinus* spp. **Pseudotsuga menziesii* **Abies* spp. **Larix* spp. **Picea* spp.	From Canada in *Pinus strobus* logs	Browne(1968) H.Geertsema[e](pers.comm.)
Scolytus multistriatus Marsham	Europe, including the U.K.; Siberia	Eastern North America (1909). Now in all U.S.A. states except Alaska, Arizona, Florida & Montana; in Canada as far west as Manitoba; Australia	†**Populus* spp. †**Prunus* spp. †*Rhamnus* spp. †**Ulmus* spp.	Unbarked elm (*Ulmus* spp.) timber from Europe	Pierce(1918) Finnegan(1957) Elton(1958) Watson&Suppell(1961) Chararas(1962) Nordin(1964) Graham(1967) Jones,T.(1967) Browne(1968) Barger&Hock(1971) Peacock&Cuthbert(1975)
Scolytus rugulosus Müller	Europe; Siberia	North America (1834); Argentina; Chile; Peru	†**Malus* †**Prunus* †**Pyrus*	Probably in nursery stock	Balachowsky(1949) Chararas(1962)
Stephanoderes birmanus (Eichhoff) =*Hypothenemus birmanus*	Burma; Hong Kong; Malaya; Papua New Guinea; Sarawaki; Queensland, Australia	Florida & Hawaii, U.S.A.; tropical Africa	Many herbaceous plants	Unknown; readily transported in berries & stems of herbaceous plants	Wood(1960) Browne(1961)
Stephanoderes georgiae Hopkins	Original native range unknown	Mariana Islands; eastern North America	Many herbaceous plants	Unknown; readily transported in twigs	Wood(1960)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Stephanoderes hampei (Ferrari) =*Hypothenemus hampei*	Tropical Africa; exact origin apparently unknown	All coffee growing areas of the world. Java (1908); Brazil (1913); Sumatra & Borneo (1919); Malaya (1929); Sri Lanka (1936); New Caledonia (1943)	†**Coffea* spp.	In coffee beans, & by berry-eating birds	Wood (1960) Browne (1961) LePelley (1973)
Xyleborus affinis Eichhoff	Cuba; New World tropics	Australia (1929); now in most tropical countries	Polyphagous on trees	Unknown	Brimblecombe (1953) Baker (1972)
Xyleborus badius	Korea; Japan	Cuba; Republic of South Africa; west coast of tropical Africa	**Cleyera japonica* **Daphniphyllum macropodium* **Fraxinus* spp. **Ilex* spp. **Meliosoma* spp. **Quercus* spp.	Into Republic of South Africa on tola & limba logs. Other modes unknown	Lee (1969) H. Geertsema[e] (pers. comm.)
Xyleborus crassiusculus (Motschulsky) =*X. semigranulosus* =*X. semiopacus*	Eastern Africa; southern Asia; Indonesia; Japan; Korea; Java; Samoa; Sri Lanka	Hawaii (1956) & South Carolina (1974), U.S.A.	**Carpinus laxiflora* **Castanea* spp. **Celtis* spp. **Cleyera japonica* †*Liquidambar* spp. †**Quercus* spp. **Styrax japonica* Other species	Unknown	VanZwaluenberg (1956) Wood (1960) Browne (1961) Gray (1972) Nobuchi (1972) Anonymous (1975a)
Xyleborus compressus (Lea)	Australia	New Zealand (1974-1975)	*Pinus radiata* *Pseudotsuga menziesii*	Freshly sawn timber, rain-drenched timber & freshly felled logs	Brimblecombe (1953) J. Bain[g] (pers. comm.)
Xyleborus fornicatus Eichhoff	Original range uncertain. Found from India to Australia; Hawaii; Micronesia; Indochina; Java; Borneo; Papua New Guinea; Taiwan; Fiji	Found wherever tea is grown. Probably introduced throughout much of its present range	†**Camellia* sp. †*Artocarpus* sp. †*Persea* sp. †*Ricinus* sp. †*Theobroma* sp. †*Hevea* sp. †*Citrus* spp. *Others*	Unknown	Brimblecombe (1953) Wood (1960) Browne (1961) Entwistle (1972)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Xyleborus rubricollis Eichhoff	Japan; Korea	Maryland, U.S.A. (1942)	**Abies* spp. †**Acer* spp. **Alnus* spp. **Castanea* spp. **Morus* spp. **Pinus densiflora* **Pinus* spp. **Populus* spp. †**Quercus* spp.	Unknown	Bright&Stark(1968) Lee(1969)
Xyleborus saxeseni Ratzeburg	Europe, North America	New Zealand (1957); Japan	Polyphagous on trees	Imported into New Zealand on battens of telephone wire, in logs, & in freshly cut timber	Chamberlin(1958) Chararas(1962) Nobuchi(1966) Bright(1968) Milligan(1969) Wertz,Skelly&Merrill (1971) Baker(1972) Kuschel(1972) Hosking(1973) Bain(1974)
Xyleborus torquatus Eichhoff	Cuba; Brazil; Puerto Rico	Australia (no record of introduction); southern Japan	Many deciduous species	Unknown	Brimblecombe(1953) Browne(1961)
Xyleborus truncatus (Erichson)	Eastern Australia	New Zealand	†**Eucalyptus* spp. †*Podocarpus* spp.	From Tasmania	Waterhouse(1964) Zondag(1964) Milligan(1970) Kuschel(1972)
Xylechinus pilosus Ratzeburg	Siberia; eastern Europe	France (1918)	†**Abies* spp. †**Larix* spp. †**Picea* spp.	Unknown, probably in imported logs	Balachowsky(1949)
Xylosandrus compactus Eichhoff =*Xyleborus morstatti*	Tropical western Africa; southern Japan; Sri Lanka; Fiji; subtropical America; Indochina; Celebes, etc.	Florida (1951) & Hawaii, U.S.A.; probably introduced to Africa	**Coffea* spp. **Cacao* spp. †**Acer* spp. †*Orchidaceae & many other species	Unknown	Browne(1961) Bright(1968) Entwistle(1972) Nobuchi(1972) Anonymous(1973) LePelley(1973) Anonymous(1975)

Table I (continued)

Family and Species	Native Range	Region or Country in which Established and Date, if known	Host Plants in Native and New Ranges[a]	Mode of Introduction	Selected References
Xylosandrus germanus (Blandford)	Korea; Japan; Taiwan	Germany (1907-1914) (1919-1924) (1952); U.S.A. (1932)	Many species of deciduous trees & conifers	Into U.S.A. on Grape vines; into Germany from Japan on Oak timber	Elton(1958) Bright(1968) Lee(1969) Schneider&Farrier(1969) Baker(1972) Entwistle(1972) Nobuchi(1972) J. P.Vité[d](pers.comm.)
Xylosandrus morigerus (Blandford) =*Xyleborus morigerus*	Malaysia	Many coffee producing countries including Sri Lanka; Fiji; Samoa; Sarawak; Philippines;Papua New Guinea; Brazil; Queensland, Australia; Germany	Coffee & many other plants. A pest of greenhouse orchids in Germany	Probably in coffee plants & possibly in orchids	Browne(1961,1968,1972) J. P.Vité[d](pers.comm.)
Xylosandrus zimmermani (Hopkins)	Unknown	Southern Florida, U.S.A.	*Ardisia* sp. *Chrysobalanus* sp. *Ocotea catesbyana*	Unknown	Baker(1972)
PLATYPODIDAE					
Crossotarsus fairmairei Chapuis	India; Sri Lanka	Japan	Many species of trees. Unknown in Japan	Probably in logs from tropical trees	Nobuchi(1973)
Platypus solidus Walker	Southern Asia & adjacent islands to Australia, excluding Japan & probably Borneo	Japan; probably Borneo & perhaps recently throughout much of its present range	†*Acacia* spp. **Araucaria* spp. †*Carpinus laxiflora* †*Cleyera japonica* **Eucalyptus* spp. †*Ficus retusa* †*Hevea* spp. †**Shorea* spp.	Probably transported in logs	Wood(1960) Browne(1961) Nobuchi(1973) Gray&Wylie(1974)
Platypus taiwansis Schedl	Taiwan	Probably Japan	†**Ficus* †**Quercus*	Unknown	Nobuchi(1973)

Notes for Table I

[a] If known, native hosts of beetles designated by *. Hosts in new ranges of beetle designated by †.

[b] Department of Zoology, Brigham Young University, Provo, Utah, 84602, U.S.A.

[c] Station de Recherches, Forestière D'Avignon, Avignon, France.

[d] Forstzoologisches Institut der Universität Freiburg im Breisgau. Fed. Rep. Germany.

[e] Plant Protection Research Institute, Ryan Road, Rosebank, 7700, Cape, Republic of South Africa.

[f] University of Wisconsin-Madison, Department of Entomology, Madison, Wisconsin, 53706, U.S.A.

[g] Forest Research Institute, New Zealand Forest Service, Private Bag, Rotorua, New Zealand.

[h] Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, U.K.

Table II. Interceptions of Scolytidae and Platypodidae by 8 timber-importing countries. Dates, if known, listed for each country, but frequency of interceptions unknown in most cases. Records compiled from official interception lists, personal communications,[a] and publications as follows: Girard (1968,1969,1970,1971,1972), Milligan (1970), and Bain (1974)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
Australia	SCOLYTIDAE	
	Arixyleborus rugosipes Hopkins	Timber from Malaya
	**Eccoptopterus sexspinosus* Motschulsky	Unbarked logs from Papua New Guinea
	Gnathotrichus retusus Lec.	Western U.S.A. coniferous timber
	**Ips grandicollis* Eichhoff	Pine sp. bark on machine cases from eastern U.S.A.
	**Scolytus multistriatus* Marsham	Unbarked elm logs from Europe
	Xyleborus apicenotatus Schedl	Cedar logs from Borneo
	Xyleborus bidentatis Motschulsky	Timber from Borneo & Papua New Guinea
	Xyleborus camphorae	Unknown
	Xyleborus canaliculatus	Logs from Papua New Guinea
	Xyleborus cognatus Blandford	Timber from Borneo
	**Xyleborus perforans* Wollaston	Timber & logs from Borneo & Papua New Guinea
	**Xyleborus similis* Ferrari	Logs from Papua New Guinea
	Xyleborus subcostatus Eichhoff	Timber from Borneo
1974	PLATYPODIDAE	
	Crossotarsus kuntzeni Schedl	Logs from Papua New Guinea

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
Australia 1974 (cont'd.)	*Crossotarsus minutus* Chapuis	Logs from Papua New Guinea
	**Crossotarsus mniszechi* Chapuis	Logs from Papua New Guinea
	**Diapus pusillimus* Chapuis	Logs from Papua New Guinea
	**Diapus quinquespinatus* Chapuis	Logs from Papua New Guinea
	Platypus dejeani Chapuis	Logs from Papua New Guinea
	Platypus jansoni Chapuis	Logs from Papua New Guinea
	Platypus shoreanus mutilatus Schedl	Logs from Borneo
	**Platypus solidus* Walker	Logs & timber from Papua New Guinea & Borneo
	Platypus turbatus Chapuis	Timber from Borneo
Canada, 1973-1974	SCOLYTIDAE	
	Hypothenemus kunnemanni (Reitt)	Infested Brazil nuts from Brazil
Germany, 1963	SCOLYTIDAE	
	Dendroctonus pseudotsugae Hopkins	In unbarked Douglas-fir logs from North America
	Hypothenemus eruditus Westw.	Bongossi wood from western Africa
	Ips calligraphus (German)	Pine timber from North America
	Leperisinus aculeatus Say	Ash timber from North America
	Monarthrum fasciatum Say	Oak timber from North America
	Monarthrum mali Fitch	Oak timber from North America

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
Germany 1963 (cont'd.)	*Xyleborus ambasius* Hag.	Samba timber from western Africa
	Xyleborus andamanensis Blandford	Teak wood from Orient
	Xyleborus conthyloides Hag.	Bongossi wood from western Africa
	Xyleborus ferrugineus Fabricius	Makore and abachi woods from western Africa
	Xyleborus mascarensis Eichhoff	Timber of many types from western Africa
	Xyleborus semiopacus Eichhoff	Bongossi wood from western Africa
	Xyleborus torquatus Eichhoff	Timber of many types from western Africa
	Xyleborus velatus Samps.	Teak from Orient
1963	PLATYPODIDAE	
	Cylindropalpus auricomus Schedl	Bongossi wood from western Africa
	Doliopygus brevis Samps.	Apa wood from western Africa
	Doliopygus dubius Samps.	Bongossi wood from western Africa
	Doliopygus serratus Strohmeyer	Apa, ilumba and limba woods from western Africa
	Doliopygus unispinosus Schedl	Samba wood from western Africa
	Platypus hintzi Schauf.	Many tropical woods from western Africa
	Platypus linearis Strohm.	Many tropical woods from western Africa

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
Kenya	SCOLYTIDAE	
	Xylosandrus morigerus (Blandford)	On orchids of unknown origin
New Zealand, 1971-1975	SCOLYTIDAE	
	Hylastes nigrinus (Mannerheim)	In wane bark of Douglas-fir sawn timber & dunnage from the western U.S.A.
	Orthotomicus laricis (Fabricius)	Pine dunnage from the Netherlands
	Xyleborus anademensis (Blandford)	Teak veneer logs from Burma
	Xyleborus ferrugineus (Fabricius)	Hardwood peeler logs from Solomon Islands
	Xyleborus soricauda (Motschulsky)	Teek veneer logs from Burma
1965-1971	*Arixyleborus rugosipes* Hopkins	Meranti sawn timber from Malaya
	Carphoborus ponderosae Swaine	Pine pallets from the U.S.A.
	Crypturgus borealis Swaine	Spruce sawn timber from North America
	Dendroctonus obesus (Mannerheim)	Spruce casewood from Canada
	Dryocoetes autographus Ratzeburg	Pine casewood from the U.S.S.R.
	Gnathotrichus materiarius (Fitch)	Douglas-fir dunnage & unspecified casewood from North America
	Gnathotrichus sulcatus Le Conte	Douglas-fir sawn timber from North America
	Hylesinus crenatus Fabricius	Ash sawn timber from Belgium

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
New Zealand, 1965-1971 (cont'd.)	*Ips grandicollis* (Eichhoff)	Pine bolts & dunnage from Australia; pine & spruce dunnage from North America
	Ips mannsfeldi Wachtl	In wane bark of pine dunnage from the U.S.S.R.
	Ips typogrophus L.	Pine stanchions & crates from the U.S.S.R.
	Leperisinus fraxini Panzer	Ash dunnage of unknown origin
	Orthotomicus angulatus (Erichson)	Pine stanchions of unknown origin
	Orthotomicus caelatus (Eichhoff)	Pine dunnage from eastern North America
	Pityogenes chalcographus L.	Pine casewood & pine dunnage from the U.S.S.R.
	Polygraphus rufipennis (Kirby)	Spruce dunnage & casewood from North America
	Scolytus scolytus Fabricius	Elm dunnage from the U.K. & Europe
	Trypodendron lineatum (Olivier)	Cedar sawn timber from North America; pine casewood from Germany
	Xyleborus perforans Wollaston	Kauri sawn timber from Fiji; sapele logs from Nigeria; raintree sawn timber from Samoa
	**Xyleborus saxeseni* Ratzeburg	Pine casewood from Germany
1948-1965	*Arixyleborus rugosipes* Hopkins	Serayah logs from Borneo
	Blastophagus minor Hartig	Coniferous casewood from the U.K.

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
New Zealand, 1948-1965 (cont'd.)	*Blastophagus piniperda* L.	Pine dunnage & casewood from northern Europe; pine casewood from Japan
	Carphoborus ponderosae Swaine	Pine casewood from eastern U.S.A.
	Crypturgus atomus Le Conte	Spruce casewood from Canada
	Crypturgus borealis Swaine	Spruce dunnage from the U.S.A.
	Dendroctonus obesus Mannerheim	Spruce dunnage from North America
	Dendroctonus ponderosae Hopkins	Pine casewood from North America
	Dendroctonus pseudotsugae Hopkins	Douglas-fir sawn timber with bark from Canada
	Dryocoetes affaber (Mannerheim)	Spruce dunnage from the U.S.A.
	Dryocoetes americanus Hopkins	Spruce dunnage from the U.S.A.; spruce dunnage from North America via Europe
	Dryocoetes confusus Swaine	Spruce dunnage from Canada
	Dryocoetinus villosus Fabricius	Hardwood dunnage from Europe; chestnut dunnage of unknown origin
	Gnathotrichus materiarius (Fitch)	Pine casewood & dunnage from the U.S.A.
	Gnathotrichus retusus Le Conte	Douglas-fir sawn timber & casewood from the U.S.A.; pine casewood from Canada via the U.K.; pine casewood from Japan
	Gnathotrichus sulcatus (Le Conte)	Douglas-fir sawn timber & casewood, & western red cedar sawn timber from western North America

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
New Zealand, 1948-1965 (cont'd.)	*Hylastes angustatus* (Herbst)	Pine dunnage of unknown origin
	**Hylastes ater* Paykull	Pine casewood from England, Australia, & Sweden; pine dunnage & cable drum battens of unknown origin
	Hylesinus crenatus Fabricius	Ash dunnage from England
	Hylurgops palliatus Gyllenhal	Spruce & pine casewood & dunnage from Europe
	Ips amitinus Eichhoff	Pine casewood from the U.S.S.R.
	Ips borealis Swaine	Spruce dunnage from eastern Canada
	Ips calligraphus (Germar)	Pine casewood & dunnage from North America
	Ips grandicollis (Eichhoff)	Pine dunnage & casewood from North America; pine dunnage from Australia
	Ips pini (Say)	Pine casewood & dunnage from eastern North America
	Ips typographus L.	Pine stanchions & casewood from Japan
	Leperisinus fraxini Panzer =*L. varius*	Ash dunnage from Europe; oak dunnage from the U.K.
	Orthotomicus angulatus (Erichson)	Pine stanchions & casewood from Japan; pinewood sample from Hong Kong
	Orthotomicus caelatus (Eichhoff)	Pine dunnage from eastern U.S.A. & Australia
	Orthotomicus erosus Wollaston	Pine casewood from Cyprus

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
New Zealand, 1948-1965 (cont'd.)	*Phloeosinus lewisi* Chapuis	*Cryptomeria* sp. casewood & dunnage from Japan
	Phloeosinus pini Swaine	Spruce dunnage from the U.S.A.
	Phloeotribus scarabaeoides (Bernard)	Olive wood for carving from Europe via England
	Pityogenes bidentatus Herbst	Pine dunnage from Sweden and Europe; cable drum batten of unknown origin
	Pityogenes chalcographus L.	Pine & spruce casewood & dunnage from Europe
	Pityogenes hopkinsi Swaine	Pine dunnage & casewood from North America
	Pityogenes quadridens Hartig	Pine casewood from Europe
	Pityokteines sparsus (Le Conte)	Unspecified dunnage from the U.S.A.
	Polygraphus poligraphus L.	Spruce casewood & dunnage from Europe
	Polygraphus rufipennis (Kirby)	Spruce, larch, fir, & pine dunnage from North America
	Pseudohylesinus nebulosus (Le Conte)	Unspecified dunnage from the U.S.A.
	Pseudopityophthorus minutissimus (Zimmerman)	Oak dunnage from the U.S.A.
	Pteleobius vittatus Fabricius	Elm casewood from France
	Scolytus intricatus Ratzeburg	Oak dunnage from Europe
	Scolytus mali Bechstein =*Scolytus sulcatus*	Hardwood dunnage from Europe

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
New Zealand, 1948-1965 (cont'd.)	*Scolytus multistriatus* Marsham	Elm dunnage & oak casewood from North America; elm dunnage from the U.K.
	Scolytus scolytus Fabricius	Elm pallets & dunnage from Europe; elm dunnage via the U.S.A. (original origin unknown); hardwood casewood from India
	Taphrorychus villifrons Dufour	Oak dunnage from the U.K. & Europe; oak pallets from France
	Trypodendron cavifrons (Mannerheim)	Spruce dunnage from Canada
	Trypodendron lineatum (Olivier)	Pine & spruce casewood from Europe; pine, poplar, & fir casewood, & Douglas-fir sawn timber from North America
	Trypodendron rufitarsus Kirby	Spruce dunnage from the U.S.A.
	Xyleborus cryptographus Ratzeburg	Spruce casewood from West Germany
	Xyleborus eurygraphus Ratzeburg	Pine casewood from Turkey & Cyprus
	Xyleborus inermis Eichhoff	Pine pallets overlaying hardwood dunnage from the eastern U.S.A.
	Xyleborus perforans Wollaston	*Agnathis* sp. sawn timber from Fiji; red meranti sawn timber from Malaya; lauan peeler logs from the Philippines
	Xyleborus rileyi Hopkins	Pine casewood from the U.S.A.
	Xyleborus solidus Eichhoff	Eucalypt poles from Australia
	Xyloterinus politus (Say)	Birch pallets from Canada

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
New Zealand (cont'd.)	PLATYPODIDAE	
1948-1974	*Platypus armipennis* Lea.	Eucalypt pole from Australia
	Platypus bifurcus Schedl	Lauan peeler logs from the Philippines
South Africa	SCOLYTIDAE	
	Dendroctonus valens Le Conte	Bark of spruce timber from Canada
	**Hylurgus ligniperda* (Fabricius)	Spruce floor boards of unknown origin
	Polygraphus rufipennis (Kirby)	White pine logs from Canada
	Xyleborus badius Eichhoff	Limba & tola logs from west coast of Africa
	PLATYPODIDAE	
	Crossotarsus externedentatus Fairmaire	Logs from northern Natal
	Doliopygus erichsoni Chapuis	*Eucalyptus maculata* logs from Argola
	Platypus bisulcat Speign.	Muratue logs from Malaya
	Platyscapulus auricomus Schedl	Doussi wood from west coast of Africa
United Kingdom, 1974-1975	SCOLYTIDAE	
	**Dryocoetes autographus* Ratzeburg	Unbarked spruce timber from Germany
	**Hylastes angustatus* Herbst	Unbarked pine timber from Germany
	**Hylastes attenuatus* Erichson	Unbarked pine timber from Germany
	**Hylastes brunneus* Erichson	Unbarked pine timber from Germany
	Hylurgopinus rufipes (Eichhoff)	Unbarked rock elm logs from Canada

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
United Kingdom, 1974-1975 (cont'd.)	**Hylurgops palliatus* Gyllenhal	Unbarked pine timber from Germany
	**Hylurgus ligniperda* Fabricius	Unbarked pine timber from Germany
	Ips amitinus Eichhoff	Unbarked spruce pulpwood & billets from Germany
	**Ips sexdentatus* Boerner	Unbarked pine timber from Germany
	Ips typographus L.	Unbarked timber & spruce pulpwood billets from Germany; ladder poles from Sweden
	**Orthotomicus saturalis*	Unbarked timber from Germany
	**Pityogenes bidentatus* Herbst	Spruce & pine timber from Germany
	**Pityogenes chalcographus* L.	Spruce timber from Germany
	**Tomicus piniperda* (L.) =*Blastophagus piniperda*	Unbarked pine timber from Germany
U.S.A., 1967-1972	SCOLYTIDAE	
	Cryphalus abietis (Ratzeburg)	Wood bark from the Netherlands
	Crypturgus mediterraneus Eichhoff	Pine crate from Portugal
	Crypturgus numidicus Ferrari	Wood bark from Portugal
	Hylastes ater (Paykull)	Wood crate & bark from Italy
	Hylastes cunicularis Erichson	Dunnage from Belgium
	Hylastes linearis Erichson	Wood bark from Italy

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
U.S.A., 1967-1972 (cont'd.)	*Hylurgops palliatus* (Gyllenhall)	Dunnage, pine bark, & crates from Belgium, Germany, Denmark, Finland, the Netherlands, Spain, and Portugal
	Hylurgus ligniperda (Fabricius)	Wood bark & crates from Italy; crates from Portugal
	Hypoborus ficus Erichson	Fig cuttings & plants from Italy & Spain
	Hypothenemus hampei (Ferrari) =*Stephanoderes hampei*	Coffee seeds from Angola, Brazil, Congo, Ethiopia, Guinea, India, Ghana, Indonesia, Malaysia, Nigeria, Tahiti, Zaire, Mexico, Lebanon, Nicaragua, Ivory Coast, Uganda, & others
	Ips acuminatus (Gyllenhall)	Wooden crates, bark, & wood from Poland, Norway, & Sweden
	Ips cembrae (Heer)	Wooden crate from Italy
	**Ips plastographus* Le Conte	Wooden crate from Mexico
	Ips sexdendatus (Boerner)	Dunnage, wood, crates with bark from Belgium, Italy, & Portugal
	Ips typographus L.	Dunnage from Germany; *Cedrus* sp. dunnage with bark from Japan
	Ips thomasi G. Hopping	Dunnage from Nova Scotia, Canada
	Leperisinus varius (Fabricius)	Dunnage from Germany
	Orthotomicus erosus (Wollaston)	Dunnage, crates, & wood with bark from Belgium, Italy, & Portugal

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
U.S.A., 1967-1972 (cont'd.)	*Orthotomicus laricis* (Fabricius)	Dunnage from Germany; crates with bark from Poland & Spain
	Pagiocerus frontalis (Fabricius)	Avocados from Columbia & Ecuador; Corn *(Zea mays)* from Peru
	Phloeosinus rudis Blandford	Dunnage from Belgium & Japan
	Phloeotribus scarabaeoides (Bernard)	Olive wood with bark from Israel, Libya, Spain, Italy, & Greece
	Pityogenes bidentatis (Herbst)	Cargo from Germany; crate with bark from Italy
	Pityogenes chalcographus (L.)	Dunnage, Nursery stock, crates & logs with bark from Belgium, Finland, Germany, the Netherlands, the U.S.S.R., Norway, & Sweden
	Pityogenes quatriens (Hartig)	Dunnage, wood with bark & crates from Italy; crates from Sweden
	**Pityophthorus pulicarius* (Zimmerman)	Cargo from Spain
	Polygraphus proximus Blanchard	*Cedrus* sp. dunnage with bark from Japan
	Scolytus amygdali Guerin-Meneville	Cucumbers from Israel
	Scolytus intricatus (Ratzeburg)	Dunnage from Europe; oak bark from Belgium & Spain
	Scolytus scolytus (Fabricius)	Dunnage from Belgium
	Taphrorhychus villifrons (Dufour)	Oak dunnage from Belgium

Table II (continued)

Country and Dates (if known)	Family and Species	Origin and Mode of Entry (if known)
U.S.A., 1967-1972 (cont'd.)	*Tomicus piniperda* (L.) =*Blastophagus piniperda*	Wood with bark, pine logs, dunnage & crates from Belgium, Italy, the Netherlands, Germany, Finland & Norway
	Trypodendron signatum (Fabricius)	Dunnage from Belgium
	Xyleborus eurygraphus Ratzeburg	Crates from Italy; Pistacia nuts from Italy & Turkey
	**Xyleborus semiopacus* Eichhoff	Coffee berries & *Cordyline terminalis* from Hawaii
	Xylechinus pilosus (Ratzeburg)	Crates from Italy
	PLATYPODIDAE	
	Platypus rugulosus Chapuis	Logs, crates, & bark from Columbia, Ecuador, Mexico, Brazil, & Panama
	Platypus solidus Walker	Wood from Truk Island

[a] Personal communications as follows: AUSTRALIA, F. D. Morgan, University of Wisconsin-Madison, Department of Entomology, Madison, Wisconsin, 53706; L. Smee, Australian Department of Health, Canberra, Australia; F. R. Wylie, Department of Forestry, Forestry Office, 80 Meiers Road, Indooroopilly, 4068, Queensland, Australia; CANADA, J. Gold, Plant Protection Division, Agriculture Canada, 1001 W. Pender St., Vancouver, B.C., Canada; NEW ZEALAND, J. Bain, Forest Research Institute, New Zealand Forest Service, Private Bag, Rotorua, New Zealand; SOUTH AFRICA, H. Geertsema, Plant Protection Research Institute, Ryan Road, Rosebank, 7700, Cape, Republic of South Africa; UNITED KINGDOM, D. Bevan, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, U.K.

[b] Species marked with * are already established in the intercepting country.

CHARACTERISTICS OF INTRODUCTION AND ESTABLISHMENT

Geographic and Climatic Factors

Elton (1958) postulated that eventually all species will become established in all regions favourable to them. Since the theory implies unlimited time, it is rather hard to disprove. I suggest that it is overly fatalistic. In a pragmatic sense, successful establishment requires certain criteria to be met. The organism must be introduced alive in a stage of its life cycle synchronized with the new environment or capable of becoming so. This of course presents a problem in adaptation from one polar hemisphere to another. A lack of diapause or the capability of extending diapause is a definite advantage.

Some tropical or subtropical species have managed to become established in temperate areas. *Crossotarsus fairmairei* Chapuis, a platypodid native to India and Sri Lanka has managed to become established on the relatively temperate Japanese island of Honshu (Nobuchi 1973). *Platypus solidus* Walker is another tropical species established in Japan (Nobuchi 1973). *Xylosandrus morigerus* (Blandford), an apparently polyphagous shoot-boring scolytid is established in an artificial tropical environment as a pest of greenhouse orchids (J. P. Vite,[1] personal communication). Conversely, very few temperate species are established in tropical areas. The reasons for this are not as obvious. Many species inhabit the tropics. As a result, interspecific competition is intense,

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[1] Forstzoologisches Institut der Universitat Freiburg im Breisgau. Fed. Rep. Germany.

and most species are quite specialized and consequently quite difficult to displace.

Associated Organisms and Predisposition of the Host Plant

The food requirements of bark and ambrosia beetles are more complicated than those of many insects. Ambrosia beetles are completely dependent on symbiotic fungi for their nourishment while most of the bark beetles exhibit varying degrees of dependency on these symbiotes (Graham 1967, Whitney 1971, Whitney and Cobb 1972, Barras 1973). Therefore the survival of introduced bark and timber beetles is contingent upon the occurrence of particular species in mycetangia and their survival on plant hosts in the site of introduction. *Ceratocystis* spp. are probably the most important fungi associated with scolytids. They appear to be somewhat specific to beetle species as well as host plants. In most cases investigated thoroughly, the fungus has been implicated in tree death. For example, *Ceratocystis ulmi* (Buisman) C. Moreau, is the pathogen responsible for the Dutch elm disease (Barger and Hock 1971). *Ceratocystis dryocoetis* Kendrick and Molnar causes the death of fir (*Abies* spp.) and other *Ceratocystis* spp. are thought to kill *Pinus* spp. that have been attacked by *Dendroctonus brevicomis* LeConte and *Dendroctonus ponderosae* Hopkins in western North America (Browne 1968, Whitney 1972).

Often successful attack by scolytids and platypodids may be dependent upon their host trees being predisposed to attack by primary invaders, often other, more aggressive bark beetles or pathogens. *X. morigerus,* when it appears as a pest of cocoa, is most often associated with root nematodes, *Pratylenchus* spp. (Entwistle 1972). *Scolytus multistriatus* (Marsh.) is not often able to produce broods in the bole of elm trees until the trees have become debilitated from *C. ulmi* infestation resulting from inoculum in twigs the preceding year (Anderson 1966). Many secondary scolytids are usually found associated with more aggresive species. Examples are the association of *Pseudohylesinus nebulosus* (LeConte) with *Dendroctonus pseudotsugae* Hopkins (Walters and McMullen 1956), and of *Ips paraconfusus* Lanier with *D. brevicomis* (Miller and Keen 1960). It is questionable whether the secondary species could become established or cause significant impact in an area that lacked the aggressive species. However, several secondary beetles have become established in various countries and have become serious pests, e.g., *Hylastes ater* (Paykull) in Australia (Browne 1968).

Host Susceptibility and Availability

Introduced organisms may encounter a suitable host species at the wrong stage of development or in insufficient quantity to allow establishment. For example, as reviewed by Phillips and Bevan (1967), the host of *Ips cembrae* (Heer), *Larix decidua* Mill. has been grown in the United Kingdom (U.K.) since 1620, and from about 1740 became the first exotic tree to be extensively planted there. It is highly unlikely that *I. cembrae* was not introduced between 1620 and 1945, the year it was believed to have come in on a consignment of German timber. The reasons for its dramatic increase to epidemic proportions in 1955 were the existence of a large crop of somewhat decadent trees, an extensive windthrow in 1953 which provided considerable breeding material and lastly, a drought in 1955 which provided ideal breeding conditions for the beetles in standing timber.

Another factor is the potential of an introduced species to switch to a new host in the region of introduction. Studies by Furniss and Schenk (1969) in an arboretum in northern Idaho suggest that there may be considerable potential for such occurrences. In this particular case *D. ponderosae* attacked seven new hosts: *Pinus banksiana* Lambert, *Pinus nigra* Arnold, *Pinus resinosa* Aiton, *Pinus rigida* Miller, *Pinus strobus* L., *Pinus sylvestris* L., and *Picea abies* (L.). Only *P. banksiana* occurs naturally within the range of the beetle. *Ips calligraphus* (Germar) is another example (Bright and Stark 1973). Originally from eastern North America, it is thought to have become established on several *Pinus* spp. in California around 1900, and has since been introduced into the Philippines where it is a minor pest of *Pinus* spp. Further evidence that additional host species may be acceptable are recorded instances of *Dendroctonus micans* Kugelann, *Ips typographus* L. and *I. amitinus* Eichhoff attacking *Picea sitchensis* (Bong.) Carr. in Europe (Jones, T. 1967; Browne 1968), *Ips pini* Say attacking *Pinus sylvestris* in Canada (Browne 1968), *Blastophagus piniperda* L. attacking *Pseudotsuga menziesii* (Mirb.) Franco in the U.K. (Browne 1968), and *Dendroctonus frontalis* Zimmerman breeding successfully in *Picea abies* (Baker 1972).

Number of Introduced Insects and Establishment Success

It is probably impossible to determine the exact number of beetles that must be introduced in order to result in an establishment per se. Obviously, the survival of at least one gravid female is required. However, many more individuals may be required to meet such prerequisites as overcoming host tree resistance by mass attack of bark beetles (Borden 1974) and the presence of enough individuals to set up a source of secondary attraction (Borden, VanderSar and Stokkink 1975) which would concentrate beetles on selected available hosts (Atkins 1966). It would appear logical to assume that the greater the number of live beetles imported, the greater their chance of becoming established.

Adaptation to New Environment

Another factor that must be considered is that of rapid adaptation to a new environment. The gene pool of an introduced species will be very small unless an enormous number of beetles has been introduced. The more introduced individuals, the greater the variability of the population and the greater the probability of successful adaptation to the environment of the new region.

Several factors favour rapid adaptation of an invading species. Because of the very low initial population levels and consequent lack of extensive genetic variation, the effects of natural selection pressures will be very pronounced. Success or failure of a species will be determined soon after introduction. Some degree of preadaptation is usually essential. For example, an inability to survive cold periods while in diapause or the lack of a winter diapause are probably the main reasons very few tropical scolytids and platypodids have become established in temperate areas (Table I).

The "Founder Effect" (Mayr 1963) implies that organisms can evolve very rapidly after their successful establishment. Most introduced pests are generalized species which have the advantage of some degree of preadaptation. Also, they adapt rapidly to exploit an available niche, sometimes displacing indigenous species. Apart from outright displacement, invading species may also exploit previously unoccupied niches or partition existing ones (Hutchinson 1959). While in the expansion state, the insect tends to retain its generalized characteristics and to be more damaging to its environment. For example, 6 introduced *Hylastes* species (Table I), would be considered rather generalized in their native ranges in that they attack a fairly large number of host species. They are rarely considered to be pests in their native Palaearctic regions where they are primarily slash-infesting. The absence of available slash, or possibly the greater susceptibility of exotic or non-host trees may result in an innocuous, generalized insect becoming a pest in areas where introduction has occurred. Swaziland, for example has over 103,000 acres in plantations of exotic pines such as *Pinus radiata* D. Don, *Pinus patula* Schlechtend. and Cham., *Pinus elliottii* Engelm., and *Pinus taeda* L. (Jones, T. 1966). Prior to the introduction of *Hylastes angustatus* (Herbst) and other serious pests, the rapid growth and desirable habits of these pines enabled them to be grown in a 15-year rotation with only one pruning and no thinning. The beetle was first noticed in 1964 and within months it had infested a 4,000 acre stand of young pines. The result was a 50% destruction of the stand (Jones, T. 1966). Similarly, *H. ater* has proven to be quite damaging to pine plantations in

Australia (Brimblecombe 1953). *Hylastes linearis* Erichson has been introduced to South Africa and could become a pest in the future (H. Geertsema,[2] personal communication).

Once a species has realized its potential host and geographic ranges, it tends to become more specialized and to be less serious a pest than in its expansion phase. *Ips sexdentatus* Boerner is one of many examples of introduced species which were most injurious immediately after their introduction. It was introduced into the U.K. from France and Germany in pitprops and timber before 1949, the year it first was noticed to be causing damage (D. Bevan,[3] personal communication; Gosling 1949; Browne 1968). Although undoubtedly still in the country, it has not been a major pest since the early 1950's.

Natural Establishment Versus that Effected by Man

Several scolytids and platypodids appear to be naturally extending their ranges in the absence of man's influence. *I. amitinus* has extended its range northward on its own accord in recent years (E. Annila,[4] personal communication), and *D. micans* has spread throughout Turkey, presumably also by itself (Acatay 1968). In many cases, however, an extension of native range has been encouraged by man's forestry

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[2] Plant Protection Research Institute, Ryan Road, Rosebank, 7700, Cape, Republic of South Africa.

[3] Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, U.K.

[4] Finnish Forest Research Institute, Unioninkatu 40A, Helsinki 17, Finland.

practices such as the provision of host material through slash, and through log transportation. There would appear to be no simple rule for distinguishing between a natural establishment and one effected by man. If the establishment is fairly recent, and the past range of the organism well documented, it can usually be assumed that man is responsible for the extension of the range. If the organism has been established for many years, e.g., over a century, the problem is much more difficult particularly if historical records on trade routes, forestry practices etc. are not available. In both cases the solution to the problem can be aided by good taxonomy, a luxury fairly unique to Europe and North America. Very few tropical countries have had many taxonomists nor do they have many now (Gray 1972). This fact plus the great preponderance of tropical insect species has led to chaos in many instances, especially in the Scolytidae. For example, *Coccotrypes indicus* (Eggers) has been recognized by three different names simultaneously, and has been known as *Coccotrypes insularis* Eggers, *Poecilips indicus* (Eggers), *Poecilips eggersi* Schedl, *Thamnurgides indicus* Eggers and *Xyleborus conspeciens* Schedl (S. Wood,[5] personal communication). Wood's studies indicate that about 57% of the Scolytidae of North and Central America have synonyms. Because of this confused taxonomy, it is virtually impossible to obtain a natural range for any but the most common tropical pests. Therefore, the apparently larger number of introduced temperate than tropical bark and timber beetles is probably an artifact. In all probability, many

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[5] Department of Zoology, Brigham Young University, Provo, Utah 84602, U.S.A.

more tropical beetles have been introduced by man and established. Some, such as the coffee berry borer, *Stephanoderes hampei* (Ferrari), have obviously been introduced by man throughout most of their ranges. Many other introduced species probably have yet to be named, let alone investigated for possible introduction.

Mode of Dispersal and Relationship to Feeding Habits

Many exotic scolytids have been established for so long that their date and mode of introduction are not known. For example, *Hylastinus obscurus* (Marsham), the clover root borer, was first noticed in North America in 1878 (Elton 1958). It could have been introduced any time in the hundred years preceding its first observation, and the actual mode of introduction is unknown.

Interception lists (Table II) demonstrate the ease and frequency with which a pest can enter a country. Scolytids are essentially borers of wood, twigs, and fruiting bodies. Their cryptic habits make them hard to detect and easily introduced.

The probability of a beetle being introduced but not necessarily established can be related to its specific feeding habits. Browne (1961) outlined the various feeding habits of scolytids and these can be extended to include platypodids.

Herbiphagy

Herbiphagy is the direct feeding on the tissues of soft herbaceous plants, apparently a rare habit for Scolytidae. The beetle would most likely be introduced with its herbaceous host plant. Presumably, *H.*

obscurus and several of the near herbiphagous insects such as *Hypothenemus* spp. were introduced in this way.

Spermatophagy

Spermatophagy, a rare habit of feeding on seeds or the outer layers of a fruit, is typified by species in the scolytid genus *Poecilips (Coccotrypes)*. Beetles with this mode of feeding may be dispersed naturally through the action of wind, water and animals. They apparently can pass through the digestive tract of birds without being injured, if the seed in which they are contained is not digested. *S. hampei* is thought to have been spread in this manner (LePelley 1968).

Phloeophagy

One of the most common habits of the Scolytidae is that of phloeophagy (phloem feeding). Many temperate scolytid pests are phloeophagous and in numerous instances girdle and kill their host tree (Anderson 1966). Phloeophagy may also be required to inoculate the host with the fungus species which is the lethal agent in many cases (Rudinsky 1962, Graham 1967). Most of the tree-killing Scolytidae are phloem feeders (Browne 1961). Species in genera such as *Ips, Dendroctonus* and *Scolytus* are most often introduced in unseasoned and unbarked logs. Many bark beetles can survive for several months if the wood does not dry out to any great extent. Therefore, they are commonly intercepted in shipments of unbarked logs, debris and dunnage (wood often of inferior grade used in the holds of ships for stabilizing the cargo). In most cases the beetles would have no problem in flying from a contaminated ship anchored in harbour to shore. It is often possible, therefore, for the beetles to become introduced even before a ship is inspected.

Xylophagy

Xylophagy is the living in or feeding on wood. Xylophagous species are rare and are not considered very destructive as they do not kill the tree. Some species in the genera *Stephanoderes, Hypothenemus,* and *Dryocoetes* feed on wood (Browne 1961). These species are probably more likely to be introduced than phloeophagous insects, because debarking does not necessarily destroy their habitat, and wood is much less susceptible to drying than is the bark. Fortunately, these insects are not likely to constitute a major problem if they are introduced.

Xylo-mycetophagy

Xylo-mycetophagy is similar to xylophagy in that tunnels are excavated in the wood by the insects. However, the mutualistic fungus that lines these tunnels is the sole food source for the insects, which are referred to as ambrosia beetles. Species with this feeding habit may be found in the scolytid genera *Xyleborus,* with well over 1,000 species (Wood 1960), *Xylosandrus, Trypodendron, Gnathotrichus* and all of the Platypodidae. Xylo-mycetophagous species are most common in the tropics.

Ambrosia beetles are generally not tree killers although non-lethal ambrosia beetles are pests in that their fungal symbionts often stain the wood. The wood is not seriously weakened, but it is degraded by unsightly dark-stained galleries and surrounding wood. Although the

Platypodidae are rarely considered to be pests of living trees, notable exceptions to this trend are *Dendroplatypus impar* (Schedl) a serious pest of *Shorea* spp. in Malaysia, *Doliopygus dubius* (Sampson), a pest of *Terminalia superba* Engl. and Diels. in tropical Africa, and *Trachyostus ghanaensis* Schedl, a serious pest of *Triplochiton scleroxylon* K. Schum in Ghana (Gray 1972). None of these species appears to be established outside its native range, but their introduction and establishment may simply be undetected as yet. In New Zealand nothofagus trees infested with *Platypus gracilis* Broun are killed because of fungal activity (Faulds 1968, Milligan 1973). Several species of scolytid ambrosia beetles can be very damaging to trees, especially seedlings. In Ghana, *Xyleborus mascarensis* Eichhoff, *Xyleborus semigranulosus* Blandford and *Xyleborus sharpae* Hopkins proved to be quite injurious to saplings of *Khaya ivorensis* A. Chev., and *Xyleborus semiopacus* Eichhoff devastated transplants of *Aucoumea klaineana* Pierre (Gray 1972).

The most common mode of introduction would appear to be in unseasoned sawn timber, dunnage, and wooden crates with bark on them. Survival of ambrosia beetles as well as reproductive activity may occur, particularly in unseasoned material. McLean and Borden (1975) found that *Gnathotrichus sulcatus* LeConte could survive for over two months and produce broods in unseasoned lumber in British Columbia. Thus, ambrosia beetles constitute a major quarantine problem to those countries shipping and importing wood (Milligan 1969). As a result, wood must often be treated before export, contributing significantly to the cost of the product. The facility with which ambrosia beetles spread through commerce from one geographical area to another is illustrated by the cosmopolitan distribution of the majority of tropical species (Wood 1960).

Directional Flow and Impact of Introductions: Unpredictable Biological and Economic Phenomena

Assuming biogeographic theory to be valid, the majority of introductions should be from the larger land mass to the smaller land mass, e.g., Europe-Asia to North America (Mayr 1963, Carlquist 1965, Darlington 1966). However, it would appear that the reverse trend is in evidence for bark and timber beetles (Table I). An examination of the opportunity each species has for being introduced, discloses that over the last few hundred years North America has been a major source of wood for a timber hungry Europe. Moreover, quarantines are of recent origin; only in the last century have people actually attempted to prevent the entry of exotic pests. In recent years the trend has changed. Bark and timber beetle species have been introduced from the old world to North America, in spite of quarantine regulations. In addition, interceptions by many countries are very high (Table II). A sea voyage that used to take months, allowing for the wood to become seasoned en route, now takes days or weeks. As a result, the wood and/or bark can more easily arrive with a complement of living organisms.

Even though very few scolytids have been introduced from Europe to North America, those that have, have become severe pests. One of the most prominent examples of the unpredictive nature of introductions and their impact is the smaller European elm bark beetle, *S. multistriatus*, the vector of Dutch elm disease, *C. ulmi* (*S. multistriatus* has also been introduced into Australia [L. Smee,[6] personal communication]). The first record of the beetle in North America was from Massachusetts in 1909, and the insect was presumed to have been introduced in the early 1900's. Two main centres of spread appear to have been New York City and southern New Hampshire, probably from separate introductions (Elton 1958). The disease was introduced separately and first observed in 1930 in Ohio in elm timber imported from Europe for veneer. Meanwhile, the beetle greatly extended its range, and is now found in all states except Arizona, Florida and Montana (Anonymous 1975a). In Canada the disease was found in the 1940's around Sorel, Québec (Finnegan 1957), 200 miles from the nearest known U.S. infection. This probably represents another separate introduction. It has now reached Winnipeg, near the extreme northwest limit of the range of American elm, *Ulmus americana* L.

The *S. multistriatus/C. ulmi* complex presents a good example of the difficulty encountered in predicting the economic impact of an introduced organism. Although Pierce (1918) included *S. multistriatus* on his potential pest list (not knowing that it was already present in the country under a synonym), *C. ulmi* was not recognized as a dangerous pathogen, and *S. multistriatus* was considered to be of little economic significance in its native range. However, native elm bark beetles in North America have proved to be good vectors of *C. ulmi*, and *U. americana* has proven to be particularly susceptible, a typical case of an unforseen phenomenon arising following introduction of an exotic pest. Both

6 Australian Department of Health, Canberra, Australia.

Hylurgopinus rufipes Eichhoff and *Scolytus sulcatus* LeConte have greatly facilitated the spread of the disease throughout the natural range of American elm (Watson and Sippell 1961, Baker 1972). As a result, a most valuable timber and ornamental tree has virtually disappeared from the forests and the cities of eastern North America. Moreover, *S. multistriatus* is probably the only exotic scolytid to recross the Atlantic with almost equal pest potential as in its introduction to North America. Infested unbarked rock elm *(Ulmus thomasii* Sarg.) logs from Toronto have been imported continuously into an unsuspecting U.K., resulting in the apparent emergence of beetles bearing a new and particularly virulent North American strain of *C. ulmi* (Brasier and Gibbs 1973). *H. rufipes* galleries in the elm bark suggest that it too has been introduced (Walker 1973), although there is no indication as yet of its establishment in the U.K. (D. Bevan,[3] personal communication).

INFLUENCE OF CURRENT TIMBER PRODUCTION AND TRADE PATTERNS ON POTENTIAL INTRODUCTIONS AND ESTABLISHMENT

To predict the probability that a particular species of beetle has for introduction into a certain country, and to identify the most vulnerable countries, it is necessary to examine timber import and export trends and policies. It is also important to examine native and exotic forest production in a country to assess both the establishment potential of a scolytid or platypodid species, and its probable economic impact if established.

Current Trade Patterns

Consideration of current timber trade patterns is facilitated by distinguishing between tropical and temperate producers and consumers, although many countries may not fall precisely into either category.

Temperate Countries in the Northern Hemisphere

The great bulk of wood produced in temperate regions is from the North Temperate Zone and is coniferous in nature.

In North America, the U.S.A. is a net importer of wood with its domestic production only supplying 89% of its needs (Anonymous 1965a). The greatest producer of exported coniferous timber is Canada and over 90% of its timber export is to the U.S.A. (Anonymous 1973), wherein lie several interesting implications. Firstly, because most of Canada's timber trees have ranges extending into the U.S., virtually all serious native bark and timber beetle pests in Canada also occur in the U.S. This situation does not preclude the necessity for stringent regulatory practices by both countries. For instance, the U.S.A. in 1973 imported 229,082 cords of unpeeled fir and spruce pulpwood from Canada. Should a European bark beetle such as *D. micans* be introduced to Canada, such import practices could serve to disperse the pest throughout the entire range of *Picea* spp. in North America.

Apart from the U.S.A., the only countries to import unbarked timber from Canada in large quantities are Japan, Germany and many of the New World countries. There is certainly a risk of new introductions. For example, in 1973, Japan imported 6,205 western red cedar logs (*Thuja* *plicata* Donn) (Anonymous 1973). Since *Thuja* spp. and several closely related *Juniperus, Chamaecyparis* and *Cupressus* species are commonly grown in Japan, the numerous Canadian *Phloeosinus* spp. might easily become established there.

Canada exports a great number of live Christmas trees to the U.S.A. (3,199,496 in 1973) and to Venezuela, Panama, Puerto Rico, Bermuda, and the Bahamas (Anonymous 1973). The major species exported are Douglas-fir *(P. menziesii)*, true fir *(Abies* spp.), Scots pine *(P. sylvestris)* and spruce *(Picea* spp.) (Anonymous 1973). Although there are no scolytid pests of significance on Christmas trees in Canada, such insects as the twig-boring *Pityophthorus orarius* Bright (Bright 1968, Hedlin and Ruth 1970) might become established on exotic Douglas-fir in other countries or other alternate conifer hosts.

The U.S.A. exports some softwood logs and several hardwoods such as maple, walnut, and birch to Canada. Various exotic tropical hardwoods are imported by both countries, but do not pose a significant risk of introducing scolytid or platypodid pests, except to the southernmost regions of the U.S.A. and to Central America. The latest scolytid introduced to North America would appear to be *Xyleborus crassiusculus* Motschulsky *(X. semiopacus)* from Southeast Asia. It was reported established in South Carolina in 1974 (Anonymous 1974a).

Europe faces more problems than does North America, partly because it comprises many different countries, each with different plant protection legislation and regulatory practices. In addition, exotic tree species, especially conifers, are planted extensively in many countries and are vulnerable to introduced scolytids and platypodids.

The countries of greatest timber production in Europe, excluding the U.S.S.R., are Norway, Sweden, and Finland. The primary timber species of this area are *P. sylvestris,* Norway spruce *(P. abies),* and in some areas, Sitka spruce *(P. sitchensis)* (Jones, T. 1967). In 1973, Sweden exported 2,551,000 m^3 of pulpwood, mostly to the U.K., the Netherlands, Germany, Denmark and France. On the other hand, Sweden imports much unbarked sawtimber from Finland, the U.S.S.R. and Poland. Because of the great threat posed to Sweden by *I. amitinus,* this importation of wood is prohibited during August and September, and unbarked timber imported between June 1st and July 31st must be kept in water for at least two weeks (B. Lekander,[7] personal communication). Unlike Sweden, Finland does have *I. amitinus* which became established after World War II, and was first detected in 1956 (E. Annila,[4] personal communication). Finland imports timber from the U.S.S.R., a highly probable source of *I. amitinus*. *I. amitinus* has been extending the northern part of its range naturally and it is quite possible that it reached Finland through natural range extension. Finland exports most of its timber to such countries as the U.K., West Germany, the Netherlands and France. Endemic bark beetles such as *D. micans* annually destroy large amounts of Scandinavian lumber (Anonymous 1965b) and secondary attackers are also quite destructive. Several North American species could probably become established, but the threat of introduction is low because very little wood is imported from North America.

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[7] Royal College of Forestry, Department of Forest Entomology, Stockholm, Sweden.

Central European countries (e.g., Germany, Switzerland, France) consume more timber than they produce and thus are timber importers. Such exotic conifer species as *P. menziesii*, *P. sitchensis*, and *P. strobus* are planted extensively. However, they have very few pest problems at least partly because of a general change in reforestation practices, e.g., the avoidance of even-aged monocultures (Jones, T. 1967). Periodic outbreaks of *D. micans* have occurred, but not of the magnitude of bark beetle epidemics in the western U.S.A. Many North American bark beetles would probably do very well in Central Europe because of acceptable climatic and forest management conditions.

The U.K., also a consuming country, imports over 90% of its wood requirements. By 1980, home production is expected to exceed 10%, resulting from past aforestation projects (Grayson 1969). Having very few native deciduous forest trees and only one significant native conifer, *P. sylvestris*, it was necessary to plant large tracts of exotic trees such as *P. menziesii*, *L. decidua*, *P. sitchensis*, *P. abies*, *Tsuga heterophylla* (Raf.) Sarg., and several *Pinus* spp., e.g., *Pinus contorta* Dougl. Forests now cover 7.5% of the land area (Jones, T. 1967). Compared with the rest of Europe, the U.K. has been hard hit by introduced scolytids. Both *I. cembrae* and *I. sexdentatus* have been introduced from continental Europe and have done significant damage to larch and pine (D. Bevan,[3] personal communication; Gosling 1949, Crooke and Bevan 1957). The U.K. is actively working to prevent the entry of *I. typographus* and *I. amitinus*, both of which have been intercepted many times. Although Browne (1968) questioned whether the climate of the U.K. is suitable for the survival of these beetles, their establishment in the past may have simply been limited by lack of sufficient host trees of the appropriate age, as was the case with *I. cembrae* (Phillips and Bevan 1967). Of all the European countries, the U.K. appears to be the most concerned over possible introductions of all pests and diseases, especially the Scolytidae.

The U.S.S.R. would appear to have no introduced species of scolytids and platypodids (S. A. Mirzoyan,[8] personal communication; Kostin 1973). It is self-sufficient in forest products and does not appear to import much in the way of wood material.

Temperate Countries in the Southern Hemisphere

Australia and New Zealand are important timber-producing countries of the South Temperate Zone. There are large plantations of exotic conifers in both countries.

Australia has at least 12 million hectares of native forest and 200,000 hectares of exotic conifers, mostly pine (Anonymous 1965b), but still imports over 1 million m^3 of sawn timber and logs per year, while exporting approximately 50,000 m^3 per year (Anonymous 1975b). Most imports come from Canada, the Baltic and Malaysia in the form of sawn timber. Eleven scolytids and probably one platypodid have been introduced to Australia (Table I). Although rather innocuous in their native countries, species such as *H. ater, Ips grandicollis* Eichhoff, and *Xyleborus perforans* Wollaston have proved to be quite destructive in their new environment. *Hylurgus ligniperda* (Fabricius), although common, is not

[8] Ministry of Agriculture, Scientific Research Institute of Plant Protection, Armenian S.S.R.

considered a pest (Browne 1968). Because of this past record of successful establishment, Australia's plant protection regulations are among the most stringent in the world.

New Zealand has 5.8 million hectares of native forest and 350,000 hectares of exotic conifers (Anonymous 1965b). The most successful plantation trees are *P. radiata* and *P. menziesii*, which comprise 90% of the exotic forests (Milligan 1970). Several *Picea* spp. cannot be grown because of the presence of a spruce aphid (Anonymous 1965b). As in Australia, large, even-aged monocultures pose many problems. At least 8 species of exotic scolytids have become established. *H. ater* has proved to be quite destructive. Others such as *Xyleborus saxeseni* Ratzeburg have proved costly, not because of the damage they do per se, but because they constitute a major quarantine problem and increase the cost of New Zealand's exports (Milligan 1969). Some species, e.g., *Xyleborus compressus* (Lea) and *H. ligniperda* have been introduced from Australia. Although New Zealand has very tough plant protection laws, several species have been recently introduced. *H. ligniperda* and *X. compressus* were first discovered in 1974 and 1972 respectively (J. Bain,[9] personal communication).

Non-Temperate Countries

This category includes examples from countries not discussed in the "Temperate" category. They range from the wet rain forests of New Guinea to the dry areas of southeast Africa, and have little in common except that most them are "third world countries." Because of the

[9] Forest Research Institute, New Zealand Forest Service, Private Bag, Rotorua, New Zealand.

incomplete taxonomy of tropical Scolytidae and Platypodidae, only the most striking and well-known of introduced species are considered.

The major tropical wood-producing countries are the Philippines (11 million m^3/yr.), and West Malaysia (5 million m^3/yr.) (Gray 1972). These are followed by Zambia, Papua New Guinea, and Guyana with considerably lesser production (Gray 1972). The countries hardest hit by introduced bark and timber beetles are those that have extensively planted exotic species, especially *Pinus* and *Cupressus* spp. Examples are the African countries, Kenya, Uganda, Tanzania, Malawi, Zambia, Rhodesia, the Republic of South Africa and Swaziland (Jones, T. 1967). Their plantations have been seriously damaged by such introduced species as *H. angustatus, Hylastes opacus* Erichson, *Hylastes pinastri* Eggers, *H. linearis* and *H. ligniperda,* none of which is considered a pest in its natural range. As in New Zealand and Australia, the beetle problem has been aggravated by the practice of establishing even-aged monocultures of exotic trees and rather poor forest sanitation. *Hylastes* spp. breed in stumps and refuse and become a problem only when their populations are allowed to build up under unnatural conditions. Attacks on exotic plantations by indigenous species are also high in some areas indicating that cultural practices are at least partially at fault.

In South America, apart from pests of rubber, coffee, and other long cultivated plants, little is known about the various bark and ambrosia beetles that occur, especially in the potential timber-producing areas such as the Amazon basin. Thus, it is virtually impossible to predict what species of insects will become pests once man seriously disturbs this area's unstable ecosystem through logging. There are undoubtedly many tropical species of Scolytidae and Platypodidae that would do very well if they were introduced into the tropical rain forests of South America.

Most of the important introduced tropical Scolytidae have been established for so long that their original range is unknown. *Coccotrypes dactyliperda* Fabr., a pest of date palms was first found and described from Germany (Browne 1961); *Stephanoderes georgiae* Hopkins and *S. hampei* also have unknown original ranges. The majority are associated with crops that have long been grown by man. *C. dactyliperda* is now nearly cosmopolitan in the tropics. However, its discontinuous distribution suggests that it has been spread by man in seeds of domesticated crops such as dates, coconuts, avocados and ivory nuts. *Coccotrypes rhizophorae* (Hopkins) breeds in the seeds of *Rhizophora mangle* L. and has probably been introduced in seeds from the Indo-Malayan region to the Caribbean (S. Wood,[5] personal communication). *Hylesinus oleiperda* Fabr. appears to be a pest wherever olives are grown and has even been introduced into Argentina, presumably in olives. *Hypocryphalus mangiferae* Stebbing has been introduced from the Orient to all mango-growing regions of the world (Browne 1968). *S. hampei* is perhaps the most destructive pest of coffee in the world and has undoubtedly been transported by man throughout the range of the coffee plant (LePelley 1968). It is a pest in virtually all coffee-growing countries except El Salvador, Guatemala, Costa Rica, and Nicaragua where it has yet to be introduced. *Xyleborus fornicatus* Eichhoff is a pest of many tropical plants such as tea, breadfruit, avocado, castor bean, citrus, cocoa, derris and rubber. It has most likely been introduced throughout much of its present range, its original range not really being known (Wood 1960). Many other introduced tropical bark and ambrosia beetles may be discovered.

PLANT PROTECTION POLICIES AND PRACTICES

All major countries in the world have enacted legislation to prevent the importation of potentially dangerous plant pests. However, many are caught in the predicament of trying to effect some measure of control over introductions without embarking on elaborate and prohibitively expensive plant protection schemes. Wood is often imported in the form of bulk cheap timber and is often processed after its arrival. Usually, it is decked in large piles and inspection is limited to the random examination of superficial logs. Even though a phyto-sanitary certificate may accompany a shipment, it may not be pest free. For example, up to 10% infestation by *I. typographus* was recently found in a certified shipment of unbarked logs imported into England from West Germany (D. Bevan,[3] personal communication). Faced with such an occurrence, the importing country has several options. The consignment can be returned to the exporting country. However, by the time of inspection, the ship has usually completed unloading the wood, and has in all likelihood departed. If treatment facilities are available, infested logs can be treated with chemicals on an individual basis, but no way has been devised to treat logs that are stacked in piles. Fumigation of such large volumes of wood on the dockside has been demonstrated to be impractical and ineffective in destroying wood-inhabiting pests. Also, destruction of the shipment and its beetles in situ would create an intolerable fire hazard and generate considerable adverse economic pressure. Therefore, the only recourse left to many authorities is to process the wood for pulp or other products as soon as possible, and to submit an official complaint to the exporting country.

A country can justify plant protection expenditures only if a large timber production industry must be protected of if small volumes of high quality timber, such as oak or chestnut, which can be inspected and treated easily are imported. To inspect large volumes of inferior grade logs or lumber would appear rather pointless. However, the importing country has the recourse of accepting only debarked timber, a practice which has many advantages. There is no possibility of introducing bark beetles and a lessened probability of ambrosia beetles being introduced. Secondly, the wood is more easily inspected and treated on arrival. Lastly, the decreased volume of the shipment with no bark would defray some expenses (Joly 1974). There is no room in plant protection practices for the allowance of tolerance limits, i.e., willingness to accept a limited degree of infestation but prohibiting large scale infestations from entering the country, or permitting a species of unknown pest potential clear entry. If the potential economic impact of a species is unknown, one must assume that it could be harmful if it were introduced. However, a review of the prohibited pest list of most countries will reveal that in order for an organism to be put on that list, it must have already been introduced into or established in that country, and in all probability is already economically important. Such lists thus become of questionable benefit. The real object of plant protection should be to prevent the introduction of all potentially dangerous organisms.

The effectiveness of various plant protection laws and practices is assessed below through their examination in selected wood-producing importing countries.

North America

If the number of potential pest organisms intercepted (Table II) is an indication of effectiveness, the U.S.A. has one of the most efficient plant protection agencies in the world. Under the Federal Plant Protection Pest Act of 1957, measures are taken to prevent the entry of any pest not occurring or widespread in the U.S.A. Port inspectors examine manufactured wood products, logs, lumber, packing and crating material, and dunnage. When insects are found the hosts are quarantined, the insects identified and fumigation or other action is taken to prevent the pest species from entering (H. S. Shirakawa,[10] personal communication). However, a critique by H. L. Jones (1972) questions the competence and efficiency of U.S. plant protection at the local level, especially the application of internal quarantines. Between Canada and the U.S.A. there is a free movement of wood (except elm timber), a practice which could promote the spread of a pest established in either

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[10] U.S.D.A. Animal and Plant Health Inspection Service, Hyattsville, Maryland 20782, U.S.A.

country. However, this free movement of wood apparently does not constitute a serious threat to the U.S.A. and probably saves a great deal of money and time.

Canada intercepts very few bark and timber beetles. Even though many of these beetles are being imported, the Agriculture Canada Plant Protection Division obviously considers other organisms a greater threat. No Scolytidae or Platypodidae occur on the prohibited pest list, a potentially dangerous omission when one considers the many European species which would probably thrive in Canada. Canada has no specific regulations governing the importation of wood with bark. Although inspection of imported wood is not mandatory, inspectors are actively encouraged to do so. Most wood encountered is seasoned and without bark attached. Elm logs with bark attached must be kiln dried at 130°F. for 12 hours. This is to prevent further entry of Dutch elm disease and its vectors.

Although not an important timber producing country, Mexico is adjacent to the U.S.A., which is. Mexico would appear to have no restrictions on any wood imports and this policy could allow potentially destructive bark and timber beetles access to Central or the rest of North America.

Europe and Asia

The small size and relatively open borders between many European countries make plant protection measures extremely difficult for individual nations. Therefore, a plan is under consideration to replace current plant protection regulations by a general Plant Health Directive applicable to all countries in the European Economic Community (D. Bevan,[3] personal communication).

The U.K. appears to have the strictest plant protection regulations of any European country. Past introductions of scolytids have proved to be quite devastating and present legislation is geared primarily to prevent the entry of *I. typographus, I. amitinus* and *D. micans* from continental Europe. The importation of elm logs with bark from any non-European country is specifically prohibited unless the wood has been treated with a malathion emulsion and is accompanied by a phyto-sanitary certificate issued by the plant protection service of the country of origin. Any coniferous wood imported from Europe must be accompanied by a phyto-sanitary certificate stating it to be free from *I. typographus* and *D. micans*. Unbarked coniferous timber from Canada is prohibited.

Since 1948, France has prohibited any importation of unbarked coniferous timber. No important species of bark and timber beetles have been introduced to France since 1952, when both *Gnathotrichus materiarius* (Fitch) and *D. micans* were discovered.

West Germany has no scolytids and platypodids on its prohibited pest list and apparently has no restrictions on the import of unbarked timber (J. Gold,[11] personal communication). Existing restrictions are on oak logs and sawn timber, the only stipulation being that they be inspected on arrival and declared free of oak wilt, *Ceratocystis fagacearum* (Bretz) Hunt, a disease known to be vectored in North America by

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[11] Plant Protection Division, Agriculture Canada, 1001 W. Pender St., Vancouver, B.C., Canada.

Pseudopityophthorus spp. (Rexrode and Jones 1970). While this policy may be good for business, it must certainly strain relations with neighbouring countries such as France, to which an exotic pest established in West Germany can easily spread. Thus, one should not be surprised that *D. micans* was first discovered in France near the West German border (P. Carle,[12] personal communication).

The Netherlands' Plant Health Import Regulations Order of 1971 specifically identifies all Scolytidae as harmful and prohibited organisms, and prohibits the importation from outside Europe of any conifer wood with bark on it. This stringent legislation protects a rather minor local forest industry, but provides excellent protection to neighbouring countries. However, such an altruistic position by the Netherlands is rendered ineffective by other countries which do not have similar laws. In direct contrast to the Netherlands, Belgium's legislation is vague. A "blanket statement" prohibits the importation of any plant or plant product infected with harmful pests and diseases. Scolytidae are not on the prohibited organism list and there are no apparent restrictions on timber importation. However, there are restrictions on the importation of some living trees, all hardwoods.

Czechoslovakian plant protection laws direct that bark beetle-infested material must be treated before it can be allowed into the country, although there are no restrictions on cut logs and sawn timber per se, and imported material need not have a phyto-sanitary certificate.

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[12] Station de Recherches, Forestières D'Avignon, Avignon, France.

Wood with roots and bark must be inspected after arrival, a practice that may allow insects to emerge prior to inspection. Secondly, the wood is only treated if an infestation is detected; this requires competent inspectors to examine entire shipments if the law is going to work.

Scandinavian countries have similar legislation and practices. Denmark, although it has no scolytids on the prohibited pest list, prohibits the importation (presumably from non-European countries) of all conifers of all genera, including logs with bark. Norway and Sweden prohibit the importation of all live conifers and all unbarked timber from overseas. However, Sweden does import much unbarked sawtimber and pulpwood from Finland, the U.S.S.R., and Poland. To prevent introduction of *I. amitinus,* Sweden prohibits imports from these countries during August and September, and round timber imported between June 1st and July 31st must be held in water for at least two weeks.

The plant protection laws of Switzerland and Austria are very similar. Austria specifically prohibits the importation of *Xylosandrus germanus* (Blandford), an oriental pest of oak, now established in Germany and North America, and the diseases *C. fagacearum* and *C. ulmi*. All live plants require an import licence and all bark-covered parts of oak, chestnut, elm and poplar are prohibited. There are no apparent restrictions on importation of coniferous wood.

Spain appears to have no restrictions on the importation of wood except that *C. ulmi* and chestnut blight *(Endothia parasitica* (Murr.)) are prohibited.

The U.S.S.R. simply prohibits forest produce with any pest known to occur within the boundaries of the U.S.S.R.

Japan's plant protection laws are, at best, vague. Although phyto-sanitary certificates are required against all "injurious animals," the legislation does not mention wood or forest pests, and no scolytids are on the prohibited pest list. Consequently, Japan imports large quantities of unbarked coniferous wood from many countries, and probably imports many bark and timber beetles as well. Japanese importers do have a policy, however, of keeping the logs in water for several weeks after their arrival, a practice which would lower but not preclude the possibility of any pests being introduced (Phillips and Bevan 1967). By not expending time and money on strict plant protection measures, Japan appears to have bowed to immediate economic demands. Because of its limited timber industry, it is unlikely to be devastated by exotic bark and timber beetles. However, Japan could act as a source of infection for the whole Orient.

Africa

All countries south of the Sahara have adopted the Inter-African Phytosanitary Legislation (I.A.P.C.). Certificates must be granted by the chief of the plant protection service of each country for permission to import any material. Prohibited are various live trees including conifers, rubber, mango, tea, olives, coffee, avocado, and cocoa. Minimal concern with scolytids, platypodids, and other forest pests is evidenced by the absence of any apparent restrictions on the importation of wood of any type, providing that the plant is dead. However, individual countries in some cases have put riders on this legislation. For instance, Zambia stipulates that coniferous wood that has been in certain parts of South Africa between November 1st and March 31st must be sterilized in an approved manner within 180 days of its arrival. Otherwise, timber exports from countries south of the Sahara are free of restrictions. The Republic of South Africa requires that all imported plant material, including timber and lumber entering its ports must be inspected at the port of arrival for insect damage. When damage is found or suspected, the offending material is either fumigated with methyl bromide or, when severely attacked, destroyed. Furthermore, no coniferous timber may be imported with bark, a restriction that is rigidly applied (H. Geertsema,[2] personal communication).

Australia and New Zealand

Australia has perhaps the strictest plant protection legislation in the world. Although there are no scolytids of platypodids on the prohibited pest list, the measures employed by the Australian plant protection agencies will obviously prevent the introduction of these beetles. All imported timber must be heat treated at 165°F. for a specified time. In addition, all packing cases must be free of wood-boring insects. Infestation may result in the destruction of the shipment and a revocation of the import licence. Australia strongly advises that cargo containers, dunnage, pallets, and packing cases be either fumigated with methyl bromide or heat treated by various means prior to transport. Imported sawn timber and plywood must be penetrated with one of an acceptable preservative and/or pesticide, such as copper, boric acid and arsenic compounds or Lindane or Dieldrin. These measures should be effective in preventing the introduction of bark and timber beetles.

New Zealand also has strict laws regarding the importation of wood and wood products. It prohibits the importation of living conifers and elms, and only seeds of these species can be brought into the country. Although no phyto-sanitary certificate is necessary for forest produce, all imported forest products must be inspected upon arrival. Suspect material may be quarantined, treated by fumigation or heat, or destroyed. The importation of bark, or any materials with bark attached is absolutely prohibited. In addition, such articles as wooden cable drums must have been treated by preservatives, fumigation or heat treatment.

Tropical Countries

Many tropical countries, such as the Philippines and Malaya, apparently have no restrictions on the importation of logs and other wood products. Therefore, wood-inhabiting pests may have been introduced, and introductions will probably continue. The expense of an elaborate plant protection service is apparently not justified, a policy supported by the fact that many tropical ambrosia beetles in such genera as *Xyleborus, Xylosandrus, Platypus,* and *Crossotarsus* have virtually cosmopolitan distribution. Until most tropical countries ascertain which species are actually native, extensive plant protection measures will be difficult to implement. The absence of such measures is undoubtedly behind the establishment of *I. calligraphus* in the Philippines.

Some tropical countries have stringent policies. Papua New Guinea has a quarantine system very similar to that employed by Australia. It has an estimated 700 to 800 native bark and timber beetle species in at least 45 genera; 30 to 40% are considered to be common throughout the Indo-Malayan region (F. Wylie,[13] personal communication). Even with such an impressive native fauna, the plant protection measures are apparently justified. It is worth noting that virtually all imported timber and wood products come from either New Zealand, Australia or Japan. Therefore, strict plant protection measures will reduce the possibility of Papua New Guinea serving as a stopping-off point for many pests that could pose a threat to Australia or New Zealand.

CONCLUSION

It is obvious that numerous species of bark and timber beetles have been introduced throughout the world (Table I) and that many of these have become serious pests of forest and other crops. In all the cases cited, man has been responsible, in some cases through accident and in other cases through sheer negligence. The rapid methods of transportation developed in the past half-century have undoubtedly increased the probability that any species has for introduction. The great number of live insects of potential pest species intercepted by the various plant protection agencies of the world (Table II) bears this out. A definite correlation exists between current trade routes and the number of potential

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[13] Department of Forestry, Forestry Office, 80 Meiers Road, Indooroopilly 4068, Queensland, Aust.

pests intercepted. Interception records also reflect the size and efficiency of a plant protection agency.

It is somewhat surprising that few, if any of the established scolytid or platypodid pests were considered economically significant in their native ranges. Regardless of the reasons, it is an obvious conclusion that the most potentially damaging pests have yet to be introduced (Table III). Many of these are polyphagous ambrosia beetles or aggressive, tree-killing bark beetles with wide host ranges. Establishment of a species such as *D. ponderosae,* for instance, could be devastating to native or exotic pine production. Not included in Table III are legions of secondary insects and minor pests. The pest potential of these insects obviously will not be known until they become successfully established.

In spite of the increased chances of introductions, and the need for increased vigilence to exclude proven pest insects (Table III), many countries employ the same plant protection measures as they did fifty years ago. Many of these same countries ignore problems or are erroneously convinced that the cure is much easier than the prevention. Very few have the foresight or the means to implement effective plant protection legislation. That enacted by such countries as New Zealand and Australia could serve as model legislation. Until such legislation is implemented worldwide, introductions of scolytids and platypodids will continue.

Table III. Selected bark and timber beetles demonstrating potential for future exotic pest status. Each evaluation category ranked in parentheses from 0 to 5, with 5 representing maximum score

Species	Pest Status and Hosts in Native Range	Pest Status in New Range(s) or on Non-Host Species as Evidence of Potential	Frequency and Location of Interceptions	Importance and Number of Potential Hosts in Possible New Ranges	Establishment Potential on Hosts in Possible New Ranges	Mean Ranking
Ips typographus L.	Extreme. Polyphagous primarily on *Picea* spp. (5)	Not established. Attacks *P. sitchensis* in Europe (4)	Frequently intercepted in New Zealand & the U.K. (4)	Very high. Potential hosts numerous, particularly in N. America (5)	Very aggressive tree killer (5)	4.6
Ips amitinus Eichhoff	Extreme. Polyphagous primarily on *Picea* spp. (5)	Not established. Attacks *P. sitchensis* in Europe (4)	Occasionally intercepted in the U.K. & New Zealand (2)	Very high. Potential hosts numerous, particularly in N. America (5)	Very aggressive tree killer. Cold tolerant (5)	4.2
Dendroctonus micans Kugelann	Extreme on several *Picea* spp. (5)	Introduced to France. Aggressive killer of *Picea* spp. Attacks *P. sitchensis* in Nordic countries (5)	Rarely intercepted (0)	*Picea* spp. very important, particularly in N. American forests (5)	Aggressive, tree-killing bark beetle (5)	4.0
Blastophagus piniperda (L.) =*Myelophilus piniperda* =*Tomicus piniperda*	High. Polyphagous on *Pinus* spp. & other conifers (4)	Established in Orient. Attacks *P. menziesii* in the U.K. (5)	Moderate only in N.Z. & the U.S.A. (2)	Very high. *Pinus* spp. & other conifers important in N. America & the south temperate region (5)	Twig killer & moderately aggressive bark beetle (4)	4.0
Blastophagus minor (Hartig) =*Myelophilus minor* =*Tomicus minor*	High. Specific to *Pinus* spp. (4)	Established in Orient (5)	Moderate only in N.Z. (1)	Very high. *Pinus* spp. important in N. America & south temperate region (5)	Twig killer & moderately aggressive bark beetle (4)	3.8

Table III (continued)

Species	Pest Status and Hosts in Native Range	Pest Status in New Range(s) or on Non-Host Species as Evidence of Potential	Frequency and Location of Interceptions	Importance and Number of Potential Hosts in Possible New Ranges	Establishment Potential on Hosts in Possible New Ranges	Mean Ranking
Dendroctonus ponderosae Hopkins	Extreme. Attacks & kills numerous species of both hard & soft pines (5)	Not established. Attacks numerous exotic species in native range including *Pinus* & *Picea* spp. (3)	Moderate only in N.Z. (1)	Very high. *Pinus* spp. extremely important throughout world (5)	Very aggressive bark beetle with wide host range & lethal fungal associate (5)	3.8
Dendroctonus frontalis Zimmerman	Extreme. Attacks & kills several hard pine species (5)	Not established. Usually in *Pinus* spp. but will breed in *Picea abies* (2)	Rarely intercepted (0)	Hard pines extremely important throughout world (5)	Very aggressive bark beetle with broad host range (5)	3.4
Gnathotrichus retusus LeConte	Moderate. Polyphagous on conifer logs & lumber (3)	Not established (0)	Frequently intercepted in N.Z. & Australia (3)	Very high (5)	High because of host range. A threat to south temperate region, Europe & Asia because of wide host range (5)	3.2
Trypodendron lineatum (Olivier)	High. Polyphagous on conifer logs (4)	Not established. Holarctic (0)	Moderate only in New Zealand (1)	Very high (5)	High. A threat to south temperate region (5)	3.0
Gnathotrichus sulcatus LeConte	Moderate. Polyphagous on conifer logs & lumber (3)	Not established (0)	Frequently intercepted in N.Z. (2)	Very high (5)	High, because of wide host range. A threat to south temperate region, Europe & Asia (5)	3.0

Table III (continued)

Species	Pest Status and Hosts in Native Range	Pest Status in New Range(s) or on Non-Host Species as Evidence of Potential	Frequency and Location of Interceptions	Importance and Number of Potential Hosts in Possible New Ranges	Establishment Potential on Hosts in Possible New Ranges	Mean Ranking
Dendroctonus pseudotsugae Hopkins	High. Host range limited primarily to *Pseudotsuga menziesii*. Can attack *Larix occidentalis* (5)	Not established (0)	Moderate in Germany & N.Z. (2)	*Pseudotsuga menziesii* extensively planted as exotic in Europe & N.Z. *Larix* spp. if susceptible important in Europe & Asia (3)	Agressive tree-killing bark beetle (4)	2.8
Ips pini Say	Moderate. Polyphagous on *Pinus* spp. (3)	Not established. Attacks *P. sylvestris* in Canada (2)	Moderate only in N.Z. (1)	Very high. *Pinus* spp. important worldwide (5)	Usually a secondary attacker may be primary. Cold tolerant (3)	2.8
Dryocoetes confusus Swaine	High. Attacks mainly *Abies lasiocarpa* (4)	Not established (0)	moderate only in N.Z. (1)	High. *Abies* spp. important, particularly in Europe & Asia (5)	Very aggressive bark beetle with lethal fungal associate. Very high if adaptable to additional *Abies* spp. Cold tolerant (4)	2.8
Scolytus ventralis LeConte	High. Polyphagous on *Abies* spp. (4)	Not established (0)	Rarely intercepted (0)	Very high. *Abies* spp. important, particularly in Europe & Asia (5)	May be aggressive primary or secondary attacker (4)	2.6
Scolytus ratzeburgi Janson	Moderate. Primarily on *Betula* spp. (3)	Not established (0)	Rarely intercepted (0)	*Betula* spp. of moderate importance in N. American forests (3)	Aggressive tree killer or secondary attacker (5)	2.2

Table III (continued)

Species	Pest Status and Hosts in Native Range	Pest Status in New Range(s) or on Non-Host Species as Evidence of Potential	Frequency and Location of Interceptions	Importance and Number of Potential Hosts in Possible New Ranges	Establishment Potential on Hosts in Possible New Ranges	Mean Ranking
Dendroctonus brevicomis LeConte	Extreme. Host range limited primarily to *Pinus ponderosa* (5)	Not established (0)	Rarely intercepted (0)	*Pinus ponderosa* not extremely important throughout world (1)	Very aggressive bark beetle. Host range may be limited primarily to *Pinus ponderosa* (3)	1.8

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CURRICULUM VITAE

Kenneth Richard MARCHANT March 1976

Personal

Born Halifax, Nova Scotia, February 5, 1950. Age 26.
Weight 135 lbs., Height 5'8", Single, Excellent Health.

Addresses

Present

Pestology Centre
Department of Biological Sciences
Simon Fraser University
Burnaby, British Columbia
Canada V5A 1S6
Telephone: (604) 291-4830, 291-4475

Permanent

51 Norice Street,
Ottawa, Ontario
Canada K2G 2X7
Telephone: (613) 224-2780

Licences Held

British Columbia Pesticide Applicators Certificates:

- Agricultural Crop Pest Control
- Forest and Forest Product Pest Control
- Non-agricultural and Non-forest Pest Control
- Landscape and Garden Pest Control
- Mosquito and Biting Fly Control
- Structural Pest Control

Education

1955-1964 Elementary School, Ottawa
1964-1969 Merivale High School, Ottawa
1969-1973 Carleton University, Ottawa
Received Honours Bachelor of Science in Biology; Undergraduate courses in all facets of Biology, Advanced courses in Entomology, Plant Physiology, Biogeography, and Evolution.
Honours Thesis: "An In-vitro Study of Seasonal Ionic Fluctuation in Sagittaria latifolia". Under supervision of Dr. I.L. Bayly.
September, 1974, Enrolled in Master of Pest Management Programme, Simon Fraser University, Burnaby, British Columbia.
Date of Completion, May, 1976.
Graduate courses in Plant Pathology, Parasitology, Biology of Entomophagous Insects,

Education (continued)

Pest Prevention and Control Systems, Biology of Forest Insects, Agricultural Insects, Plant Diseases, Weed Control, and the following practical field courses:

- Urban and Industrial Pest Management
- Forest, Wildland, and Watershed Pest Management
- Vegetable, Cereal, and Forage Crop Pest Management
- Fruit Crop Pest Management
- Management of Animal Disease Vectors

The aforementioned courses involved a rigorous 14 weeks of field work and afforded the participant with a great deal of practical experience. Thesis: Worldwide Introduction and Establishment of Bark and Timber Beetles (Coleoptera: Scolytidae and Platypodidae). Supervisor: John H. Borden (Ph.D.)

Working Experience

Instructor of Guitar, 1966-1968.

Junior Forest Ranger, 1967, summer, Hearst, Ontario. Experience in Sylviculture and Logging.

Agricultural Worker, 1968, summer, Richmond, Ontario. Experience in the Dairy Farming Industry.

Plant Research Institute, Groundskeeper, 1969, summer, Ottawa, Ontario.

Chemical Control Research Institute, Technician, summer, Ottawa, Ontario. Principal duties were determining the toxicity of insecticides, collecting forest insects in the field, rearing insects in the laboratory, and formulating insecticide solvents. 1970-1971.

Chemical Control Research Institute, Technician, summer, Ottawa, Ontario. Promoted to new job. Evaluated residual effects of insecticides, phyto-toxicity and the long term effects of systemic insecticides. 1972.

Instructor (Demonstrator), Biology Department, Carleton University, Ottawa, 1972-1973.

Driver, Richmond Bus Lines, Richmond, Ontario, 1973-1974.

Taxation Centre, Clerk, Ottawa, 1974.

Driver, (5 ton truck) and factory worker, Capital City Ice Company, Ottawa, summer, 1974.

Teaching Assistant, Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Introduction to Biology, and Ecology, 1974, 1975 and 1976.

References, Academic

Dr. B. P. Beirne, Director, Pestology Centre, Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6

Dr. J. H. Borden, Professor of Biology, Pestology Centre, Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6

Dr. H. Howden, Professor of Biology, Carleton University, Colonel By Drive, Ottawa, Ontario.

References, Working

Mr. G. G. Brett, Departmental Assistant, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C.

Dr. A. Schwarz, Visiting Assistant Professor, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C.

Dr. P. C. Nigam, Insect Toxicologist, Chemical Control Research Institute, Pickering Place, Ottawa.

Mrs. R. Grey, Senior Laboratory Demonstrator, Carleton University, Department of Biology, Colonel By Drive, Ottawa.

Mr. Gary Wilson, Manager, Richmond Bus Lines, Richmond, Ontario.