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The annex is a prescriptive part of ISPM 27.

ISPM 27
Diagnostic protocols for regulated pests

DP 27: *Ips* spp.

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CONTENTS

1. Pest Information

Ips species (Coleoptera: Curculionidae: Scolytinae: Ipini), commonly known as bark beetles, are sub-cortical phloem feeders in Pinaceae (conifer trees), especially *Pinus* (pine), *Picea* (spruce) and *Larix* (larch or tamarack) species (Cognato, 2015). In non-outbreak times, *Ips* beetles mainly inhabit weak or dead trees (Cognato, 2015). Adults and larvae kill healthy trees during outbreaks (Cognato, 2015) by destroying the phloem and cambium in tree trunks and limbs when feeding and tunnelling (Furniss and Carolin, 1977). Outbreaks can destroy thousands of hectares of healthy trees (Cognato, 2015). Some or all *Ips* bark beetles also transmit pathogenic fungi (Krokene and Solheim, 1998; Meng *et al.*, 2015), in particular blue stain fungi (genera *Grosmannia* and *Ceratocystis*, Ascomycota: Sordariomycetes, Figure 1). *Ceratocystis* fungi from *Ips* beetles also interfere with biological control of the conifer pest *Sirex noctilio* Fabricius (Hymenoptera: Siricidae) (Yousuf *et al.*, 2014). Certain climatic conditions may promote *Ips* outbreaks (Wermelinger, 2004; Breshears *et al.*, 2005; Marini *et al*., 2017). Trees injured in outbreaks are sometimes later killed by *Dendroctonus* bark beetles (Furniss and Carolin, 1977).

Native *Ips* species are present in all countries where *Pinus* and *Picea* occur naturally (Cognato, 2015). Two *Ips* species (*I. apache* and *I. grandicollis*) also occur as exotic species, especially in temperate southern hemisphere regions (Knizek, 2011; Cognato, 2015) where *Pinus* has been planted. Some *Ips* species use *Larix* as the principal host genus in their native range (Table 1). A few species use *Abies* (fir) and *Cedrus* (true cedar) as hosts during outbreaks (Wood and Bright, 1992). *Ips* species are not limited to the principal host genera provided in Table 1, as other conifers could be attacked when a principal host is not available.

There are 37 valid *Ips* species worldwide (Table 1). Phylogenetic analyses of the Ipini prompted transfer of several species to the genera *Pseudips* (Cognato, 2000) and *Orthotomicus* (Cognato and Vogler, 2001). Cognato (2015) reviews the phylogeny, taxonomy, diagnosis and biology of all *Ips* species.

Table 1. Worldwide list of *Ips* species with distribution and principal host genera (from Cognato, 2015). Principal host genera refer to hosts from which *Ips* species are most commonly collected in native range. Species targeted by this protocol are underlined.

Species	Authority	Native Distribution*	Principal host genera
Ips acuminatus	(Gyllenhal, 1827)	Eurasia	*Pinus*
Ips amitinus	(Eichhoff, 1872)	Eurasia (west)	*Picea*, *Pinus*
Ips apache	Lanier, 1991	North America (south)	*Pinus*
Ips avulsus	(Eichhoff, 1868)	North America (east)	*Pinus*
Ips bonanseai	(Hopkins, 1905)	North America (south)	*Pinus*
Ips borealis	Swaine, 1911	North America (north)	*Picea*
Ips calligraphus	(Germar, 1824)	North America, Caribbean	*Pinus*
Ips cembrae	(Heer, 1836)	Eurasia (widespread)	*Larix*
Ips chinensis	Kurenzov & Kononov, 1966	Eurasia (southeast)	*Pinus*
Ips confusus	(LeConte, 1876)	North America (west)	*Pinus*
Ips cribricollis	(Eichhoff, 1869)	North America (south), Central America, Caribbean	*Pinus*
Ips duplicatus	(Sahlberg, 1836)	Eurasia (widespread)	*Picea*
Ips emarginatus	(LeConte, 1876)	North America (west)	*Pinus*
Ips grandicollis	(Eichhoff, 1868)	North America (east, south)	*Pinus*
Ips hauseri	Reitter, 1894	Eurasia (central)	*Picea*
Ips hoppingi	Lanier, 1970	North America (southwest)	*Pinus*

(Table 1 continued on next page)

(Table 1 continued)

Species	Authority	Native Distribution*	Principal host genera
Ips hunteri	Swaine, 1917	North America (west)	*Picea*
Ips integer	(Eichhoff, 1869)	North America (west, south)	*Pinus*
Ips knausi	Swaine, 1915	North America (west)	*Pinus*
Ips lecontei	Swaine, 1924	North America (south)	*Pinus*
Ips longifolia	(Stebbing, 1909)	Eurasia (central)	*Pinus*
Ips montanus	(Eichhoff, 1881)	North America (west)	*Pinus*
Ips nitidus	Eggers, 1933	China	*Picea*
Ips paraconfusus	Lanier, 1970	North America (west)	*Pinus*
Ips perroti	Swaine, 1915	North America (north)	*Pinus*
Ips perturbatus	(Eichhoff, 1869)	North America (north)	*Picea*
Ips pilifrons	Swaine, 1912	North America (west)	*Picea*
Ips pini	(Say, 1826)	North America (widespread)	*Pinus*
Ips plastographus	(LeConte, 1868)	North America (west)	*Pinus*
Ips schmutzenhoferi	Holzschuh, 1988	Asia (Himalayas)	*Larix*, *Picea*, *Pinus*
Ips sexdentatus	(Boerner, 1767)	Eurasia (widespread)	*Pinus*, *Picea*
Ips shangrila	Cognato & Sun, 2007	Asia (east)	*Picea*
Ips stebbingi	Strohmeyer, 1908	Eurasia (central)	*Picea*, *Pinus*
Ips subelongatus	(Motschulsky, 1860)	Eurasia (east)	*Larix*
Ips tridens	(Mannerheim, 1852)	North America (west)	*Picea*
Ips typographus	(Linnaeus, 1758)	Eurasia (north and west)	*Picea*
Ips woodi	Thatcher, 1965	North America (west)	*Pinus*

* South = tropical and subtropical parts of North America. North America refers to the North American continent including countries north of Colombia. Widespread may not include all countries in the continent.

Most attacks are initiated by male beetles, who create a nuptial chamber under the bark and release semiochemicals to attract males and females to colonize the same tree. The polygynous males attract up to six females to the nuptial chamber (diameter: 7–15 mm). Females mate with the resident male and then create radiating egg galleries along the inner bark (Cognato, 2015; Figures 2 and 3). Females each lay eggs along their tunnel, these hatching after about seven days (Chararas, 1962). Larval galleries radiate from the "Y"- or "H"-shaped egg galleries (Figures 2 and 3), spreading over a span of 10–30 cm. Development requires six weeks in warm temperatures, allowing up to five generations per year in warm areas. In cooler areas, development requires up to two years (Furniss and Carolin, 1977). Adult beetles overwinter within parental breeding galleries, in forest litter, or in living wood tissue (Chansler, 1964; Lanier, 1967).

2. Taxonomic Information

Name: *Ips* DeGeer, 1775

Synonyms: *Cumatotomicus* Ferrari, 1867

Cyrtotomicus Ferrari, 1867

Taxonomic Position: Insecta, Coleoptera, Curculionidae, Scolytinae, Ipini

Table 2. Common names and synonyms of target *Ips* species, sorted by subgenera. Synonymy follows Knizek (2011).

Subgenus	*Ips* species	Common name	Synonyms
Bonips	*Ips pini* (Say, 1826)	pine engraver beetle	*Bostrichus dentatus* Sturm, 1826 *Bostrichus pallipes* Sturm, 1826 *Bostrichus pini* Say, 1826 *Tomicus praefrictus* Eichhoff, 1868 *Tomicus rectus* LeConte, 1868 *Tomicus oregonis* Eichhoff, 1869 *Ips laticollis* Swaine, 1918
	Ips plastographus (LeConte, 1868)*	California pine engraver	*Tomicus plastographus* LeConte, 1868
Cumatotomicus	*Ips sexdentatus* (Boerner, 1767)	six-toothed bark beetle	*Dermestes sexdentatus* Boerner, 1767 *Ips pinastri* Bechstein, 1818 *Ips stenographus* Duftschmid, 1825 *Ips junnanicus* Sokanovskiy, 1959
Granips	*Ips calligraphus* (Germar, 1824)	sixspined *Ips*, coarsewriting engraver	*Bostrichus calligraphus* Germar, 1824 *Bostrichus exesus* Say, 1826 *Tomicus praemorusus* Eichhoff, 1868 *Tomicus interstitialis* Eichhoff, 1869 *Ips ponderosae* Swaine, 1925
	Ips confusus (LeConte, 1876)	piñon *Ips*	*Tomicus confusus* LeConte, 1876
	Ips grandicollis (Eichhoff, 1868)	southern pine engraver	*Ips chagnoni* Swaine, 1916 *Tomicus cacographus* LeConte, 1868 *Tomicus grandicollis* Eichhoff, 1868 *Ips cloudcrofti* Swaine, 1924
	Ips lecontei Swaine, 1924	Arizona fivespined *Ips*	none
	Ips paraconfusus Lanier, 1970	California fivespined *Ips*	none
Ips	*Ips amitinus* (Eichhoff, 1872)	small spruce bark beetle, eight-toothed spruce bark beetle	*Tomicus amitinus* Eichhoff, 1872 *Ips amitinus* var. *montanus* Fuchs, 1913
	Ips cembrae (Heer, 1836)	large larch bark beetle	*Bostrichus cembrae* Heer, 1836 *Ips cembrae* var. *engadinensis* Fuchs, 1913 *Ips fallax* Eggers, 1915 *Ips shinanoensis* Yano, 1924
	Ips duplicatus (Sahlberg, 1836)	northern bark beetle	*Bostrichus duplicatus* Sahlberg, 1836 *Tomicus rectangulus* Ferrari, 1867 *Tomicus judeichi* Kirsch, 1871 *Tomicus infucatus* Eichhoff, 1877 *Tomicus infucatus* Eichhoff, 1878
	Ips subelongatus (Motschulsky, 1860)	larch bark beetle, oblong bark beetle	*Tomicus subelongatus* Motschulsky, 1860
	Ips typographus (Linnaeus, 1758)	eight-toothed spruce bark beetle	*Dermestes typographus* Linnaeus, 1758 *Bostrichus octodentatus* Paykull, 1800 *Ips japonicus* Niisima, 1909
No subgenus (*Incertae sedis*)	*Ips hauseri* Reitter, 1894	Kyrgyz mountain engraver, Hauser's engraver	*Ips ussuriensis* Reitter, 1913

**Ips plastographus* has two subspecies, *I. p. plastographus* (LeConte) and *I. p. maritimus* Lanier.

3. Detection

Ips bark beetles can be found in boles and limbs of the tree genera *Pinus*, *Picea*, *Larix* and *Cedrus*. *Pinus* and *Picea* wood are of primary economic importance to the world lumber trade. If bark is present, round wood, handicrafts, dunnage, crates or pallets suspected of originating from these tree genera could harbour *Ips*. Flying adult beetles are collected using a well-developed system of semiochemical lure-based traps (Fettig and Hilszczański, 2015).

Larvae and pupae are found in the host plant or wood products only immediately underneath the bark or in the phloem, not deeper in the wood or xylem (although some overwintering adults tunnel into the xylem, Lanier, 1967). Trees can be examined externally for symptoms of infestation (circular holes and red-brown boring dust, Figure 4).

3.1 Symptoms of infestation in living trees

Four general symptoms indicating possible attack in living Pinaceae trees are as follows:

- Yellowing, dying needles on the crown, a branch or all of the tree.
- Appearance of red-brown or yellow-brown boring dust on the bark or near the tree (Figure 4). *Ips* beetles often cause resin leakage, but only rarely cause appearance of resinous pitch tubes on the surface of the bark as in *Dendroctonus* colonization.
- Presence of intersecting maternal galleries up to 30 cm long, with lateral larval galleries, under the bark (Figures 2 and 3).
- Appearance of many small holes on the bark (e.g. ten or more 3–5 mm diameter holes in a 10 cm × 10 cm area). This is consistent with the post-emergence stage of *Ips* infestation. At this time the progeny has emerged from the tree to find unexploited bark tissue in which to establish new galleries.

Several months or more after successful colonization, the attacked tree may change leaf colour to yellow-green or red as the tree dies. *Ips* beetles sometimes kill healthy trees when beetle populations are high, although some trees recover even after the beetles have successfully reproduced in their tissues.

3.2 Collecting specimens from plants and wood products

The bark can be removed from affected trees or wood products using a sharp, strong knife or a small axe. The wood underneath the bark layer and the inner bark can be inspected for “H”- or “Y”-shaped galleries (or similar, Figures 2 and 3). A 40× magnifying lens can be used to inspect galleries for adults, larvae and eggs. If gallery engravings are present, some of the bark or affected material should be collected and photographed. Infested materials can be transported using a sealed bag or container. Double bagging of samples is useful for preventing escape.

Detected adults, larvae, pupae or eggs can be removed using forceps. Larvae can be placed for 30 to 60 seconds in near boiling water (90 °C to 100 °C) to fix for long-term preservation. Specimens should then be stored in a glass vial containing 70% to 80% ethanol. Adults can be killed in ethanol or by placement into a dry tube and then in a freezer at either −20 °C for at least 24 h or −80 °C for at least 6 h before card- or point-mounting on a pin. If specimens are to be saved for DNA analysis it is recommended that they be stored in a preservative such as a high percentage (>95%) of ethanol or propylene glycol.

It is necessary to collect any adults present because adults have important diagnostic morphological characters. It is not possible to identify juveniles to genus or species level based on morphology. In the laboratory, adult specimens should be mounted for examination while larvae, pupae or eggs should be examined in ethanol. See sections 4.1 and 4.2 for details on preparation of specimens for identification.

4. Identification

The genus *Ips* can be recognized and identified to species level by adult external morphology. Adult structures are illustrated in Figures 5 and 6. Descriptions and regional keys to the species of *Ips* based

on morphology are available (Balachowsky, 1949; Kurenzov and Kononov, 1966; Grüne, 1979; Schedl, 1981; Wood, 1982; Holzschuh, 1988; Lanier *et al.*, 1991; Pfeffer, 1995; Cognato and Sun, 2007). A generic key to Scolytinae larvae of eastern Canada is available (Thomas, 1957) but juvenile stages cannot be used for reliable identification on a global scale. Although *Ips* species have been discovered and identified using DNA sequence data (Cognato and Sun, 2007), validated protocols for universal DNA identification of *Ips* species have not yet been developed (Chang *et al.*, 2012). Additional work is needed to demonstrate that DNA sequence records provide accurate identification of the target species and to determine how to interpret DNA similarity between the target and non-target species.

4.1 Morphological identification of beetle adults

4.1.1 Preparation of adults for morphological examination

Ethanol preserved specimens (section 3.2) are transferred to a dish filled with 70% to 80% ethanol, to be cleaned of dirt, debris and frass. Specimens can be cleaned by gently brushing with a fine-hair artist's paint brush. The integument must be clean to show the surface texture and setal punctures. Adult specimens preserved in ethanol to be point-mounted on a pin should first be dried by removing the specimen from ethanol, blotting it with paper towel and allowing it to air-dry for 2–5 min. Specimens removed from −20 or −80 °C freezers should be placed on blotting paper and thawed for 10–20 min or until any visible condensation evaporates from the specimen. A triangular point mount can be used, attaching the beetle to the point along the right side of its thorax. Specimens may, alternatively, be glued ventrally to the middle of an 11 × 4.5 mm mounting card. Ideally the left lateral, dorsal and ventral views should be free and visible for examination. Once adults are pinned, they may be examined under a dissecting microscope capable of 40× magnification or higher (a higher magnification may be preferable). Strong, diffuse lighting is important for examination of adult bark beetles to see the surface sculpturing. Because adult bark beetles are shiny, light reflected from specimens may make it difficult to see surface structures. The sheen can be reduced by placing tracing paper or translucent drafting film between the light source and the specimen.

4.1.2 Identification of adults in the subfamily Scolytinae

Wood (1986) provides a key to the world genera of Scolytinae. Rabaglia (2002) provides an updated key to the North American genera of Scolytinae. The Scolytinae can be recognized by the following set of adult morphological characters (Hulcr *et al*., 2015):

- Body cylindrical (nearly circular in cross-section).
- Head width in dorsal view at least half of pronotal width.
- Legs and antennae (Figure 7) short (shorter than maximum body width in most, hind legs up to two-thirds of body length in a few Xyleborini), and flattened in cross-section in most.
- Tarsi of legs with four visible tarsomeres (tiny fourth tarsomere is hidden between the third and fifth).
- Antennae (Figures 5, and 8(e) to (g)) are geniculate (bent or elbowed) with: a long basal segment (the scape); an angled junction with a series of one to seven bead-like antennomeres (the funicle); and a compressed 3-segmented apical club (intersegmental sutures visible or not).
- The head anterior to the eyes is not elongated into a snout (Figures 6, and 8(a) to (d)). A snout or rostrum is present in most other Curculionidae (weevils).

Additional confirmatory characters for use in diagnosing damaged specimens are as follows:

- Eyes flush (level) with surface of head (Figures 8(a) to (d)). Eyes of many similar-shaped Bostrichidae protrude.
- Ventrally, the pregular sclerite (= submentum) is visible with a pregular suture present (Figure 6: pregula).
- Anterior legs of *Ips* and most other Scolytinae have socketed denticles on their apical and posterior edges (Figure 9(a)). Such spine-like hairs are also present in three other weevil

subfamilies. Magnification greater than 100× is required to separate socketed denticles from nearby non-socketed spines.

- The first tarsomere (the basal tarsal "segment") is approximately as long as the second and third tarsomeres combined (Figure 5).

4.1.3 Identifying adults of the tribe Ipini Bedel, 1888

Ips belongs to the tribe Ipini and can be distinguished from most other Scolytinae by the concave elytral declivity surrounded by large spines. The following tribal-level diagnostic characters are modified from Wood (1986):

- Compound eye (Figures 5, and 8(a) to (d)) sinuate (narrowed at mid-height), ventral half narrower than dorsal part.
- Antennal scape (basal segment) slender elongate, funicle 5-segmented, club either obliquely truncate or sutures on posterior face strongly displaced toward apex (Figures 5, and 8(e) to (g)).
- Pronotum (Figures 5 and 10) strongly declivous on anterior half (posterior half approximately horizontal, anterior half descends abruptly), with large asperities (broad spines).
- Procoxae contiguous, intercoxal piece deeply notched or absent.
- Protibia with three or four socketed denticles (Figure 9(a)).
- Scutellum visible in dorsal view (Figures 5 and 11(a)).
- Elytral declivity moderately sulcate to strongly excavated, sides with tubercles or spines in most (Figures 7 and 12).
- Vestiture hair-like (not scale-like or wider at midlength than at base), except for branched hairs at anterior opening of prothorax (Figure 8(g), row of hairs to right of antennal club).

Also: Frons sexually dimorphic in most.

4.1.4 Identification of *Ips* adults

Ips can be separated from other members of the tribe Ipini by features of the antennal club and elytral declivity, combined. The following diagnostic characters are modified from Wood (1986), as modified by Cognato (2000) and Cognato and Vogler (2001):

- Body length 2.1–8.0 mm (most are larger than 3 mm). Other Ipini are 1.0–4.3 mm long.
- Antennal club flattened (thickness less than one-third maximum width) and marked by sutures (Figures 8(e) to (g)). Sutures nearly straight to strongly bisinuate (not procurved).
- Elytral declivity broadly and deeply excavated, with sides acutely elevated and armed by three or more pairs of spines (Figures 7, 10 and 12). Apices of spines aligned with edge of declivity. Second spine (beginning from dorsal part of declivity) acute in lateral profile. Lower edge of concavity with an acutely elevated, explanate transverse ridge separating declivital excavation from apical edge (Figure 12(f)). Apex of declivity is not visible in dorsal view.

Ips is most similar in appearance to two other Ipini genera that also inhabit Pinaceae: *Orthotomicus* Ferrari, 1867 and *Pseudips* Cognato, 2000. *Ips* can be distinguished from *Orthotomicus* by the pointed second spine of its elytral declivity (right-angled in many *Orthotomicus*) and the broader explanate edge of its elytral declivity (Figure 12(f) vs 12(g)). *Ips* can be distinguished from *Pseudips* by its straight, bisinuate or acutely angulate antennal club sutures (Figures 8(e) to (g)). These sutures are broadly procurved (curved away from the antennal base at the midline of the club) in *Pseudips*, and also in the tropical, angiosperm feeding *Acanthotomicus* Blandford, 1894 and the warm-climate, ambrosia feeding *Premnobius* Eichhoff, 1878. *Pityogenes* Bedel, 1888 and *Pityokteines* Fuchs, 1911 are conifer-feeding Ipini, recognized by their small size (1.8–3.7 mm) and the rounded edges of their elytral declivity. The tropical, ambrosia fungus feeding *Premnophilus* Brown, 1962 lacks visible antennal sutures.

Most *Ips* species are grouped into subgenera, based on phylogenetic results by Cognato and Vogler (2001) and Cognato and Sun (2007). Diagnostic characteristics (external morphology only) of subgenera are as follows: *Cumatotomicus* Ferrari, body length >5 mm, spines on first and second elytral intervals

on declivity; *Bonips* Cognato, elytral declivity with four spines per side, elytral disc without punctures on intervals; *Granips* Cognato, elytral declivity with five to six spines per side; *Ips* DeGeer, elytral declivity with four spines per side, elytral disc without punctures on intervals; *Incertae sedis*, several *Ips* species outside any named subgenus. It is not necessary to identify to subgenus level in order to identify *Ips* species.

4.1.5 Key to distinguish *Ips* adults from other Scolytinae

The following key is modified from Wood (1986).

1. Anterior edge of elytra procurved or armed with spines or asperities (Figure 11(b)).....**not *Ips***

– Anterior edge of elytra straight or transverse, without asperities (Figure 11(a)) **2**

2. Apex of protibiae and dorsal (outer) ridge with only a single spine (Figure 9(b), circled part), or mesotibiae wider at midlength than apex .....**not *Ips***

– Apex of protibiae with multiple spines and denticles (Figure 9(a)), and mesotibiae widest at apex (as in Figures 9(a) and (b)).....**3**

3. Eye sharply, deeply emarginate, lower half usually almost equal in width to upper half; elytral declivity flattened to convex, unarmed by spines or large tubercles.....**not *Ips***

– Eye shallowly sinuate (Figure 8(a)), its lower half distinctly narrower than above; elytral declivity elaborately excavated, with lateral edges armed by three to six pairs of spines (Figures 7, 10 and 12)
.....
.....**4**

4. Elytral declivity narrowly bisulcate, sides broadly elevated, rounded, and armed by three or fewer pairs of spines; posterior margin of declivity rounded; most shorter than 3 mm.....**not *Ips***

– Elytral declivity broadly, deeply excavated, sides acutely elevated and armed by three or more pairs of spines (Figures 7, 10 and 12), posterior edge of declivity with an acutely elevated (Figures 12(f) and (g), circled), transverse ridge separating declivital excavation from elytral apex; most longer than 3 mm
.....**5**

5. With one or more of the following characteristics: sutures of antennal club absent, or procurved; elytral declivity with spines between the edge of the declivity and the elytral suture; second declivital spine obtuse or right-angled in lateral profile, or explanate apex of declivity absent or narrower or wider than length of second declivital spine (Figure 12(g)). Body length 1.4–4.3 mm.....**not *Ips***

– Sutures of antennal club weakly to strongly bisinuate (Figures 8(e) to (g)); elytral declivity with all spines in line with edge of declivity (Figures 7, 10 and 12), second declivital spine acute in lateral profile; explanate apex of declivity wider than length of second declivital spine (Figure 12(f)). Body length 2.1–8.0 mm..... ***Ips***

4.1.6 Species identification of *Ips* adults

Diagnostic characters of *Ips* spp. adults are based on key characters and diagnostic notes in Cognato (2015). The closely-related (Cognato and Sun, 2007) species *I. confusus* and *I. paraconfusus*, and also *I. cembrae* and *I. subelongatus*, are not fully distinguished from each other in the key to species. This may be important as these species may differ in their biology and distribution and whether they are a regulated pest or not (Stauffer *et al*., 2001). Additional examination by *Ips* specialists with appropriate reference collections is required to identify these beetles to species level using morphology (Cognato, 2015). DNA studies have been published to support identification of *I. confusus* and *I. paraconfusus* (Cognato *et al*., 1995; Cognato and Sun, 2007) and *I. cembrae* and *I. subelongatus* (Stauffer *et al*., 2001; Cognato and Sun, 2007) but these studies have not yet been developed into identification tests. In this protocol, 14 species are treated as target species (section 4.1.8) based on their known pest status

according to CABI and EPPO (1997). However, other *Ips* can also cause tree mortality, especially if introduced outside their native ranges.

Ips species are distinguished primarily by characters of the elytra and frons. Experts usually begin identifications by counting declivital spines. Here the following characters are useful: the number of spines on the declivity (not including small denticles on the first elytral interval); the distance from the first spine to the elytral suture relative to its height or to its distance from the second spine (Figures 13(a) and (b)); and the shininess of the declivity compared to the elytral dorsal surface (Figure 12(a) vs (b)). Several characters come from the third declivital spine (Figure 14): its pointedness (acute, subacute or nearly right-angled, and obtuse or rounded) and its profile (simple (triangular); straight-sided with acute apex; pedunculate (narrower near base than near apex); hooked (with second point on ventral side); double-pointed (appearing like two basally fused spines)). On the elytral disc (the horizontal part of the elytra), the presence or absence of punctures on the interstriae (elevated smooth surfaces between striae) are important (Figures 13(c) and (d)), especially on the second and third interstriae midway between the anterior edge of the elytra and the declivity.

On the frons (Figures 8(a) to (d)) the following presence or absence characters are used: presence or absence of a median tubercle; of a median carina (between median tubercle and labrum if both present); of a median fossa or pit (above median tubercle if present); of scattered circular tubercles; of setae; of dense setal brushes obscuring integument; or of setal punctures. A few species pairs can only be distinguished by the number of ridges on the pars stridens (Lanier *et al.*, 1991), a stridulatory organ at the posterior of the head capsule. However, this technique is not included in this protocol because it is only required for a few localized non-target species and because it requires removal of the head.

4.1.7 Key to diagnose adults of target *Ips* species

NT = non-target species.

1. Elytral declivity with three spines (Figure 12(c)); or frons with dense setae hiding part of integument; or frons protruding near epistoma; or frons without tubercles above level of eyes ...**non-target species: *I. acuminatus* (Gyllenhal), some *I. borealis* Swaine, some *I. pilifrons* Swaine, some *I. tridens* Swaine**

– Elytral declivity with four to six spines (Figures 12(a), (b), and (d) to (g)); frons evenly convex, not partly hidden by dense setae, and with tubercles above level of eyes (Figure 8(c)) **2**

2. Elytral declivity with six spines per side (Figure 12(a), counts do not include small spines on the first interval) **3**

– Elytral declivity with four to five spines per side (Figures 12(b), and (d) to (g)) **5**

3. Elytral disc without punctures between striae (Figure 13(c), on interstriae 2–3 between basal quarter and apical third); elytral declivity with fourth spine largest (Figure 10(d)); and frons with transverse carina .....***I. sexdentatus* (Boerner)**

– Elytral disc with punctures between striae (Figure 13(d), as restricted above); elytral declivity with third spine largest in most (Figure 12(a), although fourth spine is largest in some ♀ *I. calligraphus*); frons without transverse carina.....**4**

4. Pronotal width 1.7 mm or less.....***I. apache* Lanier** (NT)

– Pronotal width 2.0 mm or more.....***I. calligraphus* (Germar)**

5. First suture of antennal club nearly straight (Figure 8(e)).....**6**

– First and second suture of antennal club sinuate or acutely angulate (Figures 8(f) and (g)).....**8**

6. Elytral declivity with third spine tapered (Figure 14(a)) or straight-sided with tapered apex (Figure 14(b)) ..... ***I. borealis* Swaine, part** (NT)

– Elytral declivity with third spine pedunculate (Figure 14(c)) **7**

7. Frons with median tubercle (Figure 8(a)); body length 3.5–4.8 mm (Palaearctic)
..... ***I. amitinus* (Eichhoff)**

– Frons without median tubercle; body length 2.7–3.5 mm (Nearctic)..... ***I. perroti* Swaine** (NT)

8. Sutures of antennal club acutely angulate (Figure 8(g)); elytral declivity with five spines in most (Figures 12(b) and (d)) **9**

– Sutures of antennal club sinuate (Figure 8(f)); elytral declivity with four spines (Figures 12(e) and (f)) **19**

9. Elytral declivity with four spines (Figures 12(e) and (f))..... **10**

– Elytral declivity with five spines (Figures 12(b) and (d)) **11**

10. Frons with median epistomal tubercle connected to frontal tubercle by a vertical carina (Figure 8(b), requires magnification >50× and diffuse light)..... ***I. integer* (Eichhoff)** (NT)

– Median epistomal tubercle not connected to frontal tubercle..... ***I. plastographus* (LeConte)**

11. Frons with median tubercle split (Figure 8(d)) (or transverse pair of tubercles)
..... ♂ ***I. lecontei* Swaine**

– Frons with median tubercle entire (Figure 8(a)) or absent **12**

12. Frons with median tubercle absent (females only)..... **13**

– Frons with single entire median tubercle (males & females) **15**

13. Distance between first and second declivital spines greater than from suture to first spine (Figure 13(a)) ..... ***I. lecontei* Swaine and *I. grandicollis* (Eichhoff)**

– Distance between first and second declivital spines not greater than from suture to first spine (Figure 13(b)) **14**

14. Frons with central fovea impressed (circular impression mid frons, above tubercle if present)..... ***I. confusus* (LeConte) and *I. paraconfusus* Lanier; *I. hoppingi* Lanier** (NT)

– Frons with central fovea not impressed..... ***I. montanus* (Eichhoff)** (NT)

15. Distance between first and second declivital spines greater than from suture to first spine (Figure 13(a)) ..... ***I. grandicollis* (Eichhoff) part; *I. paraconfusus* Lanier, part; *I. cribricollis* (Eichhoff)** (NT)

– Distance between first and second declivital spines not greater than from suture to first spine (Figure 13(b)) **16**

16. Frons with central fovea weak (shallow concavity) or absent
..... **non-target species, including *I. hoppingi* Lanier**

– Frons with central fovea impressed..... **17 (diagnostically difficult species)**

17. Elytral declivity with third spine pointed (Figures 14(a) to (c), acute or subacute) **18**

– Elytral declivity with third spine rounded (Figure 14(e), not at arrow) ..... ♂ ***I. confusus*** **(LeConte)**

18. Frons with median tubercle separated from epistoma by distance less than half its diameter, central carina absent ..... ♂ ***I. paraconfusus*** **Lanier, part;** ***I. montanus*** **(Eichhoff), part** (NT)

– Frons with median tubercle (Figure 8(a), circled) separated from epistoma (Figure 8(a), arrow) by distance equal to or more than half its diameter, central carina present (Figure 8(b)) or absent ..... ***I. montanus*** **(Eichhoff), part** (NT)

19. Frons with median tubercle absent **20**

– Frons with single entire median tubercle (Figure 8(a)) **27**

20. Elytral disc without punctures between striae (Figure 13(c)) **21**

– Elytral disc with punctures between striae (Figure 13(d)) **24**

21. Elytral declivity with third spine simple: tapered from base (Figure 14(a)), or straight-sided with tapered apex (Figure 14(b)) **22**

– Elytral declivity with third spine apex emarginate (Figure 14(d)) ..... ***I. emarginatus*** **(LeConte)** (NT)

22. Body length 2.0–3.0 mm ..... **non-target species:** ***I. avulsus*** **(Eichhoff),** ***I. bonanseai*** **(Hopkins) (some ♀)**

– Body length 3.0–4.5 mm **23**

23. Frons with central fovea impressed ..... **non-target species:** ***I. nitidus*** **Eggers,** ***I. bonanseai*** **(Hopkins),** ***I. perturbatus*** **(Eichhoff)**

– Frons with central fovea absent ..... ♀ ***I. pini*** **(Say), part, also non-target species:** ***I. bonanseai*** **(Hopkins) (♀) and** ***I. perturbatus*** **(Eichhoff)**

24. Elytral declivity with distance between first and second spines less than height of first spine ..... ***I. cembrae*** **(Heer) and** ***I. subelongatus*** **(Motschulsky)**

– Elytral declivity with distance between first and second spines greater than or equal to height of first spine **25**

25. Elytral declivity with third spine tapered and acute (Figure 14(a)), or straight-sided with tapered or rounded apex (Figure 14(b)) **26**

– Elytral declivity with third spine straight-sided with acute apex, pedunculate (Figure 14(c)), or bidentate (Figure 14(d)) ..... **non-target species:** ***I. nitidus*** **Eggers,** ***I. chinensis*** **Kurentsov & Kononov,** ***I. knausi*** **Swaine,** ***I. stebbingi*** **Strohmeyer**

26. Elytral declivity with distance between bases of spines 2 and 3 similar to (at least 85%) distance between spines 1 and 2 ..... ***I. hauseri*** **Reitter**

– Elytral declivity with spine 2 closer to spine 3 than to spine 1 (distance between 2 and 3 is less than 75% of distance between 1 and 2) ..... ***I. duplicatus*** **(Sahlberg) (some ♀)**

27. Elytral disc without punctures between striae (Figure 13(c)) **28**

– Elytral disc with punctures on interstriae (Figure 13(d)) **31**

28. Elytral declivity with third spine evenly tapered (Figure 14(a)) or emarginate at apex (Figure 14(d)) ..... **some ♀ of *I. pini* (Say), and non-target species: *I. avulsus* (Eichhoff), *I. bonanseai* (Hopkins), *I. emarginatus* (LeConte)**

– Elytral declivity with third spine pedunculate (Figure 14(c)) or straight-sided with tapered apex (Figure 14(b)) **29**

29. Elytral declivity with matt appearance (Figure 12(c)); if declivity shiny then frons with median tubercle up to three times tubercle diameter from base of epistomal setae, frons median tubercle not connected to epistoma by carina, elytral declivity with third spine pedunculate
..... ***I. typographus* (Linnaeus) and *I. nitidus* Eggers** (NT)

– Elytral declivity shiny (Figure 12(b)) and frons with median tubercle two to three times tubercle diameter from base of epistomal setae, frons median tubercle connected to epistoma by carina or not, and elytral declivity with third spine pedunculate or not **30**

30. Head with median frontal tubercle connected to epistomal tubercle (Figure 8(a), requires magnification >50× and diffuse light) ..... ***I. bonanseai* (Hopkins)** (NT)

– Head with median frontal tubercle not connected to epistomal tubercle ..... ***I. pini* (Say), part**

31. Head without median epistomal carina; frons median tubercle separated from base of epistomal setae by at least twice its diameter (Figure 8(a)), median fovea present, vertex with many coarse punctures; elytral declivity with third spine straight-sided with acute apex, or pedunculate (Figure 14(c)) ..... ***I. duplicatus* (Sahlberg) (♂ & most ♀)**

– Any of above not true: head without epistomal carina; frons median tubercle separated from base of epistomal setae by only its diameter, median fovea absent, vertex with few scattered punctures; elytral declivity with third spine evenly tapered (Figure 14(a)) or apically emarginate (Figure 14(d))
..... **non-target species: *I. borealis* Swaine and *I. knausi* Swaine**

4.1.8 Diagnostic notes on target species (Modified from Cognato, 2015)

Notes on diagnosis, distributions and hosts are provided below to supplement information presented in the species key. Body lengths are rounded to the nearest 0.5 mm (except for *I. pini* and *I. montanus*).

Subgenus *Bonips*

I. pini (Say, 1826) (Figure 7). Principal hosts: *Pinus* spp. Diagnosis: *I. pini* has four spines on the elytral declivity, and lacks punctures on elytral intervals 2 and 3 near the midlength of the disc. Body length: 3.0 to 4.5 mm. *I. pini* should be diagnosed using the key or a full description that includes interspecific variation and sexual dimorphism. This species differs from the related species *I. avulsus* and *I. bonanseai* as follows:

- *I. avulsus* (Eichhoff, 1869). Principal hosts: *Pinus* spp. Differs from *I. pini* in the non-pedunculate profile of the third spine of the male declivity, the short expansion of the declivital apex, and its smaller size, 2.1–2.8 mm (Wood, 1982).
- *I. bonanseai* (Hopkins, 1905). Principal hosts: *Pinus* spp. Differs from *I. pini* in that the median frontal tubercle is connected to the epistomal tubercle, and it is a smaller size, 2.9–3.4 mm.

I. plastographus (Eichhoff, 1868), (*I. p. plastographus* (LeConte) and *I. p. maritimus* Lanier), (Figures 8(a) and 12(j)). Principal hosts: *Pinus contorta* and *Pinus muricata*. Diagnosis: This species has four spines on the elytral declivity and is similar to *I. pini* (Figure 7). Body length: 3.5–6.5 mm.

I. plastographus lacks a frontal carinate elevation and differs from the related species *I. integer* as follows:

- *I. integer* (Eichhoff, 1869). Principal hosts: *Pinus* spp. Sibling species to *I. plastographus*, diagnosable by the connection of the median epistomal and frontal tubercles by a carinate elevation or by molecular phylogenetics (Cognato and Sun, 2007). These species are potentially sympatric in northwestern North America. However, *I. plastographus* is mostly restricted to two hosts, *P. contorta* and *P. muricata*.

Subgenus *Cumatotomicus*

I. sexdentatus (Boerner, 1767) (Figure 10(d)). Principal hosts: *Pinus* spp. and *Picea* spp. Diagnosis: *I. sexdentatus* has six spines on the elytral declivity. This species differs from all other *Ips* spp. in having the largest spine in the fourth position (Figure 10(d)). Body length: 4.5–8.0 mm. This Palaearctic species is not closely related to the North American six-spined species *I. calligraphus* (Figure 12(a)) and *I. apache*, which have the largest spine in the third position.

Subgenus *Granips*

I. calligraphus (Germar, 1824) (Figure 12(a)). Principal hosts: *Pinus* spp. Diagnosis: *I. calligraphus* has six spines on the elytral declivity (Figure 12(a)) and its general appearance is like *I. apache*. Body length: 3.5–7.0 mm. This species differs from *I. sexdentatus* in that the third declivital spine of *I. calligraphus* is the largest. It is distinguished from other *Ips* spp. by the presence of three spines beyond the third declivital spine. It differs from *I. apache* (Lanier *et al.*, 1991) in the distance between the ridges of the pars stridens and by being a larger size, with a pronotal width of 2.0–2.1 mm (1.6 mm in *I. apache*).

I. confusus (LeConte, 1876) (Figure 10(b)). Principal hosts: *Pinus edulis* and *Pinus monophylla*. Diagnosis: *I. confusus* has five spines on the elytral declivity. Body length: 3.0–5.5 mm. This protocol does not reliably distinguish *I. confusus* from *I. paraconfusus*. *Ips confusus* differs from *I. paraconfusus* in the distance between the ridges of the pars stridens.

- *I. hoppingi* Lanier, 1970. Principal hosts: Pinyon pines including *Pinus cembroides* and *P. discolor*. Sibling species to *I. confusus*, from which it is diagnosed by the distance between the ridges of the pars stridens (Lanier, 1970) or by molecular phylogenetics (Cognato and Sun, 2007).
- *I. montanus* (Eichhoff, 1881). Differs from *I. confusus* and *I. paraconfusus* in the absence of the frontal fovea; the male major median frontal tubercle displaced from the epistoma; and some specimens are larger, 4.6–5.4 mm.

I. paraconfusus Lanier, 1970. Principal hosts: *Pinus attenuata*, *Pinus coulteri*, *Pinus jeffreyi*, *Pinus lambertiana* and *Pinus ponderosa*. Diagnosis: Body length: 3.5–5.0 mm. This species has five spines on the elytral declivity and is most like *I. confusus* (Figure 10(b)). The *Ips* species that are most similar to *I. paraconfusus* differ from it as follows: *I. confusus* differs in characters of the pars stridens (not presented here); *I. montanus* has more and larger frontal punctures, lacks a median frontal fovea, the male major median frontal tubercle is displaced from the epistoma, and some specimens are larger, 4.6−5.4 mm; and *I. hoppingi* is only partly distinguishable from *I. paraconfusus* by methods presented here.

I. grandicollis (Eichhoff, 1868) (Figures 8(g), 12(b), 15). Principal hosts: *Pinus* spp. Diagnosis: Body length: 2.5–5.0 mm. There are five spines on the elytral declivity and its general appearance is like *I. confusus* (Figure 10(b)). This species differs from *I. confusus* in that declivital spine 1 is closer to the second spine than to the suture, and from *I. cribricollis* in the width of the female pars stridens and the presence of a central fovea on the male frons in *I. grandicollis* (Lanier, 1987).

I. lecontei Swaine, 1924 (Figure 12(i)). Principal hosts: *Pinus ponderosa* and *Pinus pseudostrobus*. Diagnosis: Body length: 3.5–5.0 mm. This species has five spines on the elytral declivity and is most like *I. confusus* (Figure 10(b)). This species differs from all other species with five declivital spines in having a pair of median frontal tubercles on the epistoma (Figure 8(d)).

Subgenus *Ips*

I. amitinus (Eichhoff, 1872) (Figure 10(a)). Principal hosts: *Picea* spp. and *Pinus* spp. Diagnosis: *I. amitinus* has four spines on the elytral declivity. Body length: 3.5–5.0 mm. This species differs from all other Eurasian *Ips* spp. in that the antennal club sutures are nearly straight (as in Figure 8(e)). Body length: 3.5–5.0 mm. It differs from the morphologically similar North American *I. perroti* (2.5–3.5 mm) in its larger size.

I. cembrae (Heer, 1836) (Figure 12(l)). Principal hosts: *Larix* spp. Diagnosis: Body length: 4.0–6.5 mm. *I. cembrae* has four spines on the elytral declivity and is most like *I. typographus* (Figure 10(e)). This species differs from *I. typographus* by having a shiny elytral declivity and interstrial punctures of the elytral disc. It differs from the morphologically similar North American *Picea*-feeding species and *I. woodi* in the space between the first and second spines, which is less than the length of the first spine in *I. cembrae*. It differs from its sister species *I. subelongatus* in its less setose elytral declivity, but these species are best diagnosed using DNA data (Stauffer *et al.*, 2001).

I. subelongatus (Motschulsky, 1860) (Figure 12(k)). Principal hosts: *Larix* spp. Diagnosis: There are four spines on the elytral declivity. Body length: 4.0–6.5 mm. This species differs from *I. typographus* (Figure 10(e)) in having a shiny elytral declivity and interstrial punctures of the elytral disc. This species differs morphologically from *I. cembrae* only slightly, in having a more densely setose elytral declivity. DNA methods have been reported for distinguishing between these two species (Stauffer *et al*., 2001). It differs from the morphologically similar North American *Picea*-feeding species and *I. woodi* in the space between the first and second spines, which is less than the length of the first spine in *I. subelongatus*.

I. duplicatus (Sahlberg, 1836) (Figure 10(c)). Principal hosts: *Picea* spp. Diagnosis: *I. duplicatus* has four spines on the elytral declivity. Body length: 2.5–4.5 mm. This species differs from many other *Ips* spp. in the position of the first spine of the elytral declivity, which is closer to the elytral suture than to the second spine. It differs from the morphologically similar Himalayan species, North American *Picea*-feeding species and *I. woodi*, in having a sparsely granulate frons. This species differs from the similar *I. hauseri* (Figure 12(h)) in the close proximity of the bases of spines 2 and 3 in *I. duplicatus* (less than the distance between the first and second spines).

I. typographus (Linnaeus, 1758) (Figure 10(e)). Principal hosts: *Picea* spp. Diagnosis: *I. typographus* has four spines on the elytral declivity. Body length: 3.5–5.5 mm. This species differs from most other species in its dull elytral declivity (in most specimens) and impunctate interstriae on the basal half of the elytral disc. *I. nitidus* can be distinguished from most *I. typographus* specimens by its shiny declivity, and all specimens can be distinguished by phylogenetic analysis of DNA (Cognato and Sun, 2007). It differs from the morphologically similar Himalayan species, North American *Picea*-feeding species and *I. woodi* in having a major median frontal tubercle.

No subgenus: *Incertae sedis*

I. hauseri Reitter, 1894 (Figure 12(h)). Principal hosts: *Picea* spp. Diagnosis: Body length: 3.5–5.5 mm. There are four spines on the elytral declivity and its general appearance is like *I. duplicatus* (Figure 10(c)). This species differs from all other European *Ips* spp. in the position of the first spine of the elytral declivity, which is closer to the elytral suture than to the second spine. It differs from the morphologically similar Himalayan species, North American *Picea*-feeding species and *I. woodi* by having a sparsely granulate frons. This species differs from its sister species *I. duplicatus* in the separation of the bases of the second and third spines (nearly equal to the distance between the first and second spines in *I. hauseri*).

4.2 Morphological identification of larvae in the subfamily Scolytinae

While adult specimens are needed to confirm the genus-level identification of *Ips* species, it is useful to examine larvae if no adults are available. However, they may be confused with other similar Scolytinae larvae.

Ips larvae are indistinguishable from some species in other genera. Morphological examination of larvae will not allow positive identification but may allow elimination of some candidate genera. Methods are provided to indicate if a larva is either not *Ips* or suspected to be *Ips*.

4.2.1 Preparation of larvae for morphological examination

The ethanol preserved specimens can be transferred to a small Petri dish filled with 70% ethanol for morphological examination. Specimens should be clean of debris and frass prior to examination (especially the head). Specimens can be cleaned by gently brushing with a fine camel-hair brush. They may be examined under a dissecting microscope capable of 40× magnification or higher (higher magnification is better).

4.2.2 Identifying larvae in the subfamily Scolytinae

Mature larvae are 2–6 mm long. Larvae of this subfamily have no legs (Figure 15). The body is soft with three thoracic segments and ten abdominal segments. The mouthparts and head capsule are sclerotized, and are pale brown in most specimens. The head capsule is globular and not retracted into the first thoracic segment; the antennae have one segment; and the cranium has a "Y"-shaped ecdysial suture. The thorax has three pairs of pedal lobes (where legs would be), each with two to four setae. Each abdominal segment has two or three tergal (dorsal) folds. The prothorax and the first eight abdominal segments bear spiracles (Bright, 1991).

Ips larvae are difficult to distinguish from larvae of weevils (and of other Curculionidea in general). They are mainly recognizable as Scolytinae because of their presence in complex gallery systems with multiple larvae. Other non-Scolytinae beetle larvae that may co-occur in such galleries have thoracic legs allowing them to actively colonize bark beetle galleries.

4.2.3 Key to distinguish final instar *Ips* larvae from some other Scolytinae

Ips larvae in their final instar stage may be distinguished from some other Nearctic and Palaearctic conifer-feeding genera. The key below is based on work by Thomas (1957), with only 15 genera examined from mostly North American fauna. This key may help determine that some larvae are not *Ips*, but it should not be used for positive identification of *Ips*. *Ips* larvae cannot be identified to species level using morphology.

1. Posterior part of the premental sclerite rectangular, lightly pigmented (Figure 16(c)) ..... **Not *Ips***

– Posterior part of the premental sclerite of the labium acute, and dark at midline (Figures 16(a) and (b)) **2**

2. The three postlabial setae (ventral side of head capsule) arranged in a triangle (middle pair most distant from each other) (Figure 16(b)), or posterior pair not the most distant from each other across midline of head ..... **Not *Ips***

– The three postlabial setae arranged in a line (Figure 16(a)), and posterior pair furthest apart **3**

3. Six or more dorsal epicranial setae on head capsule ..... **Not *Ips***

– Five or fewer dorsal epicranial setae on head capsule **4**

4. Labial palps 1-segmented, or appearing 1-segmented ..... **Not *Ips***

– Labial palps 2-segmented (Figure 16(a), near midline) **5**

5. Epipharynx with three pairs of median setae ..... **Not *Ips***

– Epipharynx with more than three pairs of median setae **6**

6. Labium with two anteromedian setae ..... **Not *Ips***

– Labium with four anteromedian setae, outer pair smaller ..... ***Ips*** **(and some other genera)**

5. Records

Records and evidence should be retained as described in section 2.5 of ISPM 27 (*Diagnostic protocols for regulated pests*).

In cases where other contracting parties may be adversely affected by the results of the diagnosis, the following records and evidence and additional material should be kept for at least one year in a manner that ensures traceability: preserved pinned or slide-mounted specimens and photographs of distinctive taxonomic structures.

6. Contact Points for Further Information

Further information on this protocol can be obtained from:

Michigan State University, 288 Farm Lane, Room 243 Natural Science Building, East Lansing, MI 48824, United States of America (Anthony I. Cognato; email: cognato@msu.edu; tel.: +1 517 432 2369).

NPPO–NL, Ministry of Economic Affairs, NVWA (Dutch Food and Consumer Product Safety Authority), National Reference Centre, Geertjesweg 15, 6706 EA, Wageningen, Netherlands (Brigitta Wessels-Berk; email: b.f.wessels@nvwa.nl; tel.: +31 3 17 49 68 35, +31 8 82 23 29 41).

Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, K.W. Neatby Building, 960 Carling Avenue, Ottawa, Ontario, K1A0C6, Canada (Hume Douglas; email: hume.douglas@canada.ca; tel.: +1 613 759 7128).

Norwegian Institute of Bioeconomy Research, Division of Biotechnology and Plant Health, Box 115, N-1431 Ås, Norway (Torstein Kvamme; email: Torstein.Kvamme@nibio.no; tel.: +47 915 73 942).

A request for a revision to a diagnostic protocol may be submitted by national plant protection organizations (NPPOs), regional plant protection organizations (RPPOs) or Commission on Phytosanitary Measures (CPM) subsidiary bodies through the IPPC Secretariat (ippc@fao.org), which will in turn forward it to the Technical Panel on Diagnostic Protocols (TPDP).

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8. References

The present annex refers to ISPMs. ISPMs are available on the International Phytosanitary Portal (IPP) at https://www.ippc.int/core-activities/standards-setting/ispms.

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9. Figures

Figure 1. Blue stain fungus (*Ceratocystis* sp.) affecting wood of *Pinus* sp. Scale bar: 5 cm.
Source: Ronald F. Billings, Texas Forest Service, United States of America, Bugwood.org.

Figure 2. Partial *Ips calligraphus* maternal galleries in *Pinus* wood with radiating and intersecting larval galleries. The central “H”-shaped gallery was built by one male and four females. One adult female (black) and two pupae (white) are shown with arrows. Scale bar: 5 cm.
Source: William M. Ciesla, Forest Health Management International, Bugwood.org.

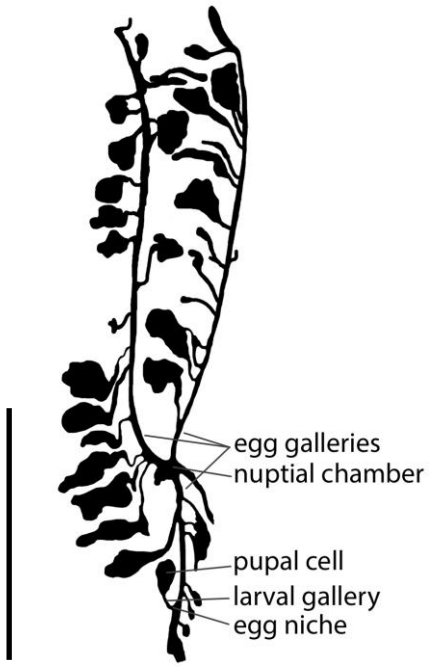

Figure 3. Partial *Ips pini* gallery system. The central "Y"-shaped gallery was built by one male and three females. Scale bar: 5 cm.
Drawing courtesy of K. Savard, Agriculture and Agri-Food Canada, Ottawa, Canada.

Figure 4. Bark of fallen *Pinus* sp. tree with boring dust from dense population of *Ips pini*. Scale bar: 5 cm.
Source: Brytten Steed, United States Department of Agriculture Forest Service, Bugwood.org.

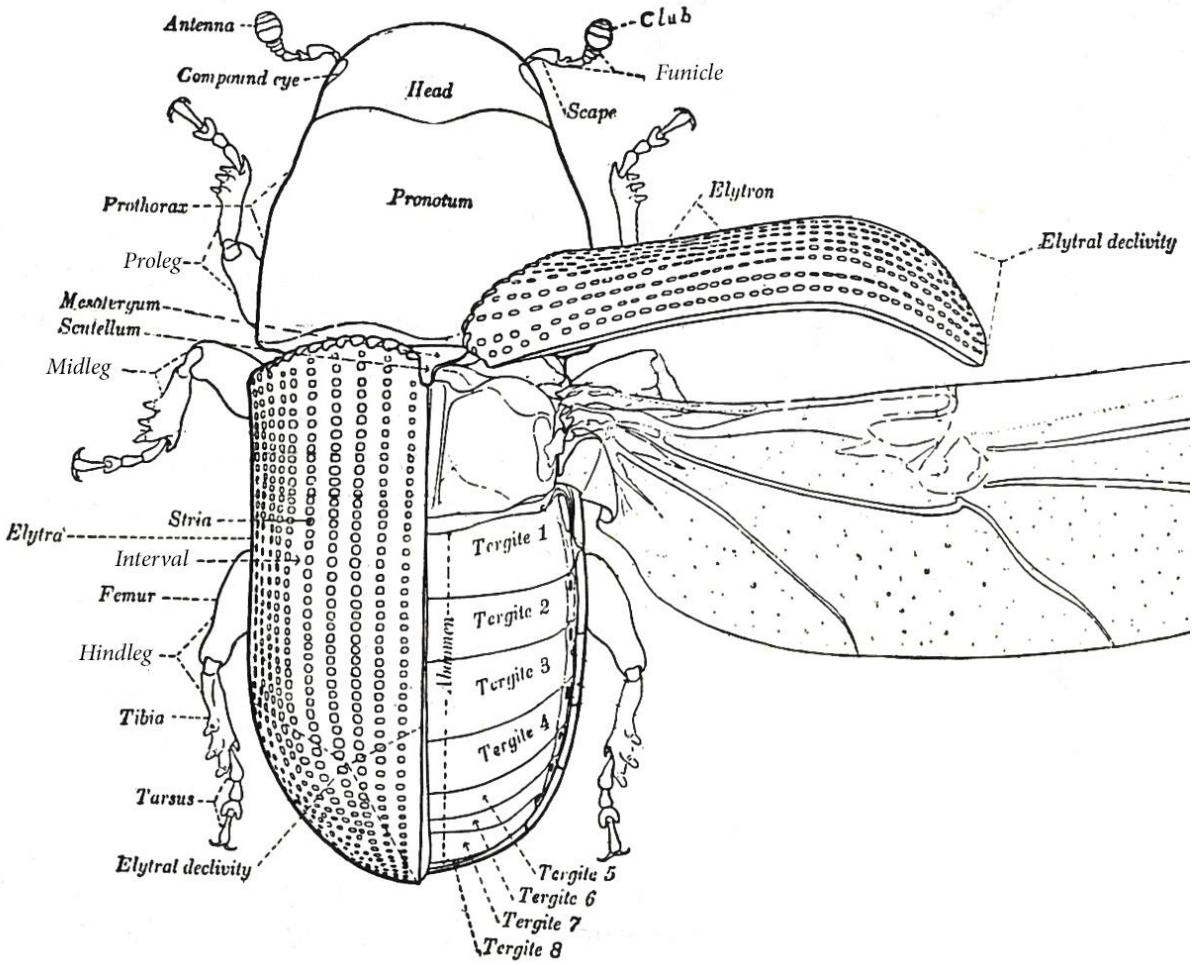

Figure 5. Morphology of an adult bark beetle (*Dendroctonus valens*) in dorsal view.
Modified from Hopkins (1909).

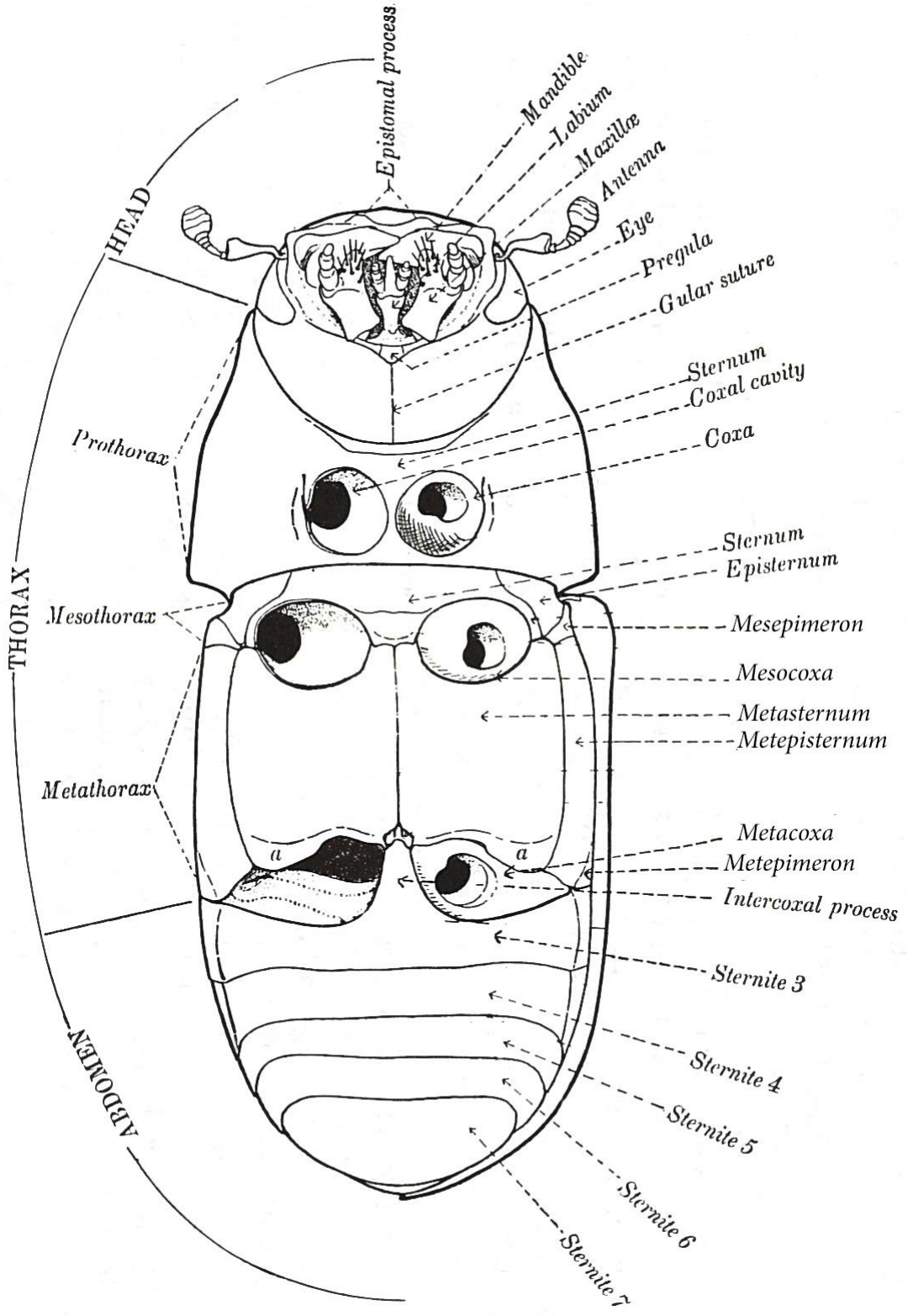

Figure 6. Morphology of an adult bark beetle (*Dendroctonus valens*) in ventral view.
Modified from Hopkins (1909).

Figure 7. *Ips pini*: dorsal habitus of adult.
Photo courtesy of K. Bolte, Canadian Forest Service, Ottawa, Canada.

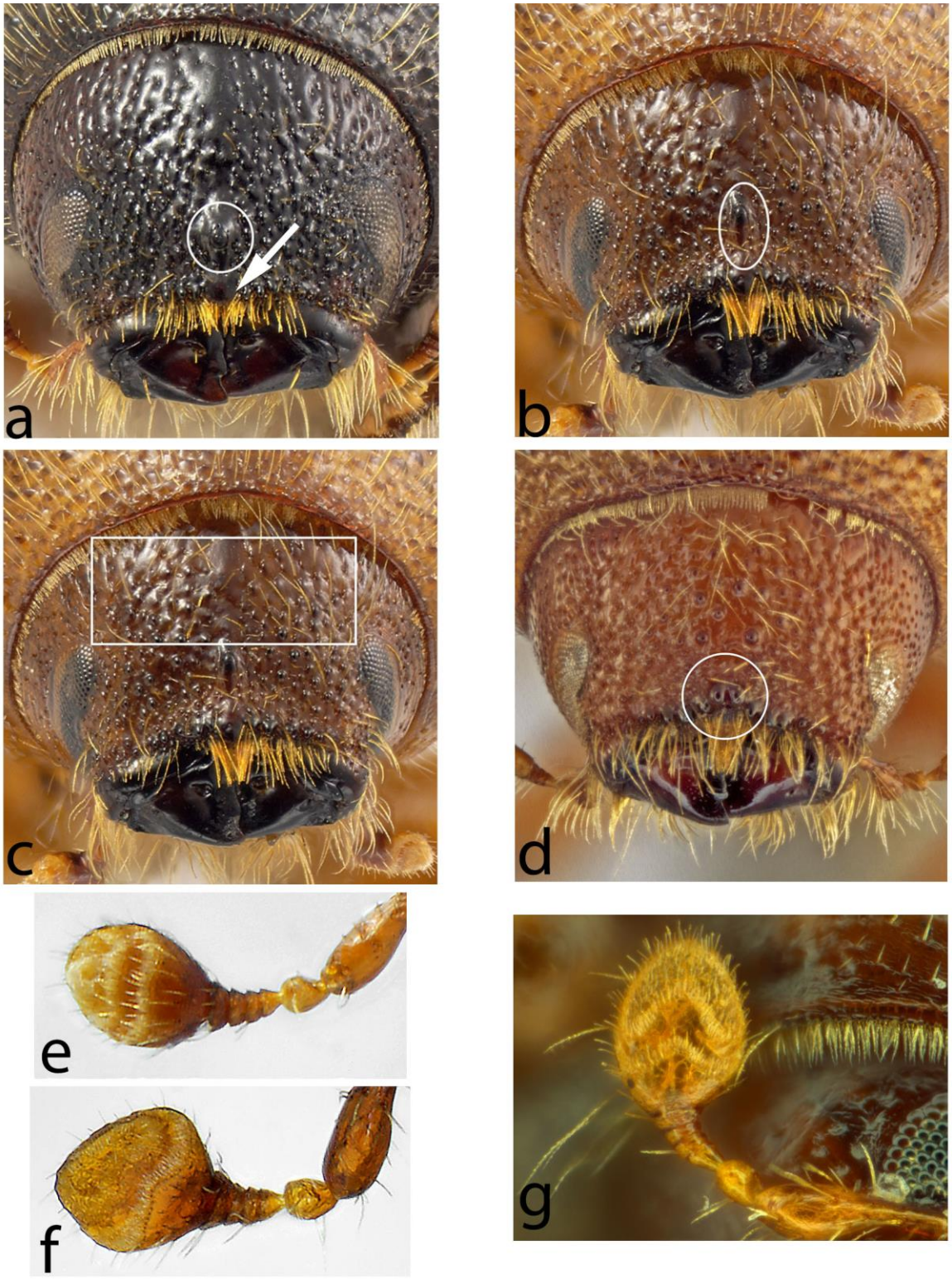

Figure 8. (a)–(d) Head of *Ips* spp.: (a) *I. plastographus* with round median tubercle (circled) and epistoma marked with an arrow; (b) *I. integer* with elongate frontal tubercle (in vertical white oval); (c) *I. integer* with tubercles on frons above eyes highlighted; (d) *I. lecontei* with split frontal tubercle. (e)–(g) Antenna of *Ips* spp.: (e) *I. perroti* (straight sutures); (f) *I. tridens* (bisinuate sutures); (g) *I. grandicollis* (angulate sutures).
Photos courtesy of (a)–(c), (e) and (f) K. Bolte, Canadian Food Inspection Agency; (d) K. Savard, Agriculture and Agri-Food Canada, Ottawa, Canada (AAFC); (g) H. Douglas (AAFC).

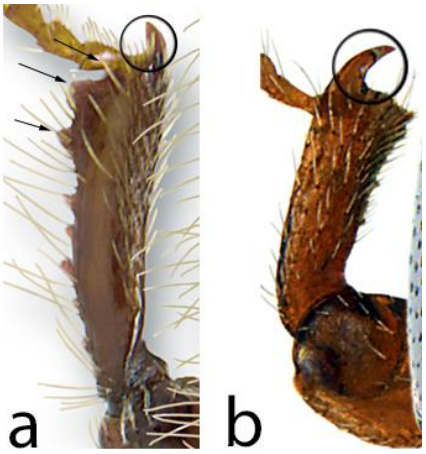

Figure 9. Front tibia of Scolytinae spp.: (a) *Ips pini*, (b) *Scolytus multistriatus*. Arrows indicate socketed denticles; circle surrounds apical non-socketed spine.
Photos courtesy of K. Bolte, Canadian Forest Service, Ottawa, Canada.

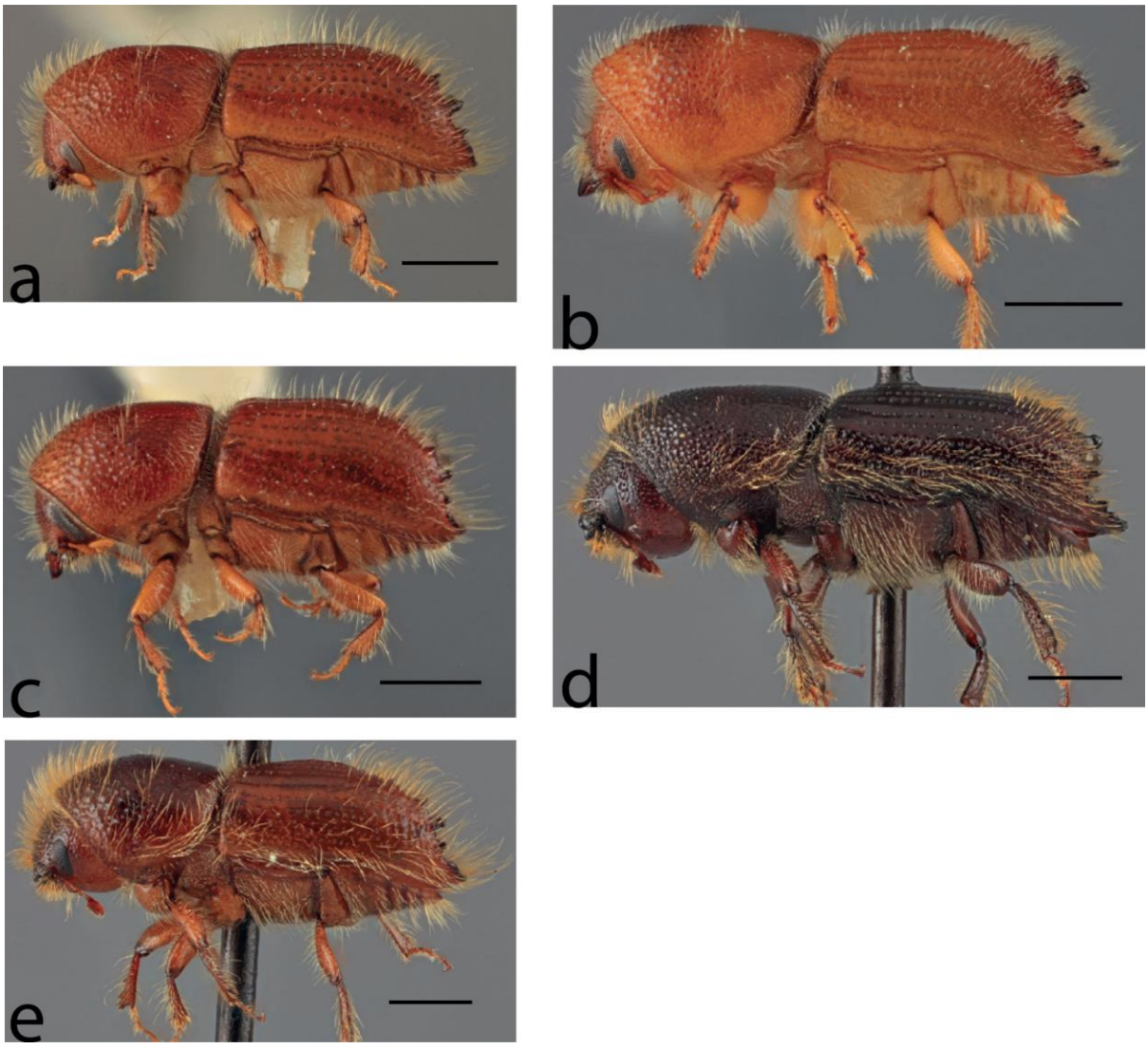

Figure 10. Lateral habitus of *Ips* spp.: (a) *I. amitinus* (four spines); (b) *I. confusus* (five spines); (c) *I. duplicatus* (four spines); (d) *I. sexdentatus* (six spines); (e) *I. typographus* (four spines). Scale bars: 1 mm.
Source: Cognato (2015).

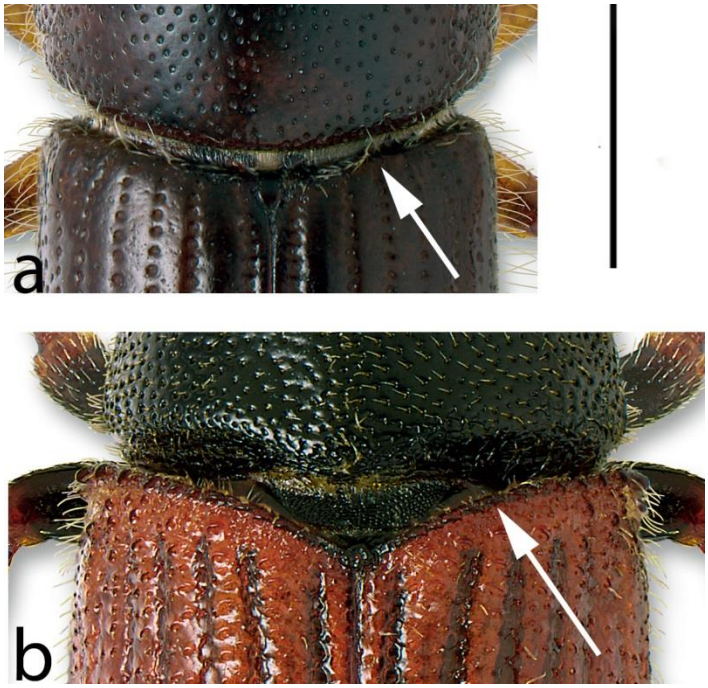

Figure 11. Shape of elytral base (arrow): (a) not procurved and smooth, *Ips pini*; (b) procurved and asperate (with spines), *Phloeosinus punctatus*. Scale bar: approximately 1 mm.
Photos courtesy of K. Bolte, Canadian Forest Service, Ottawa, Canada.

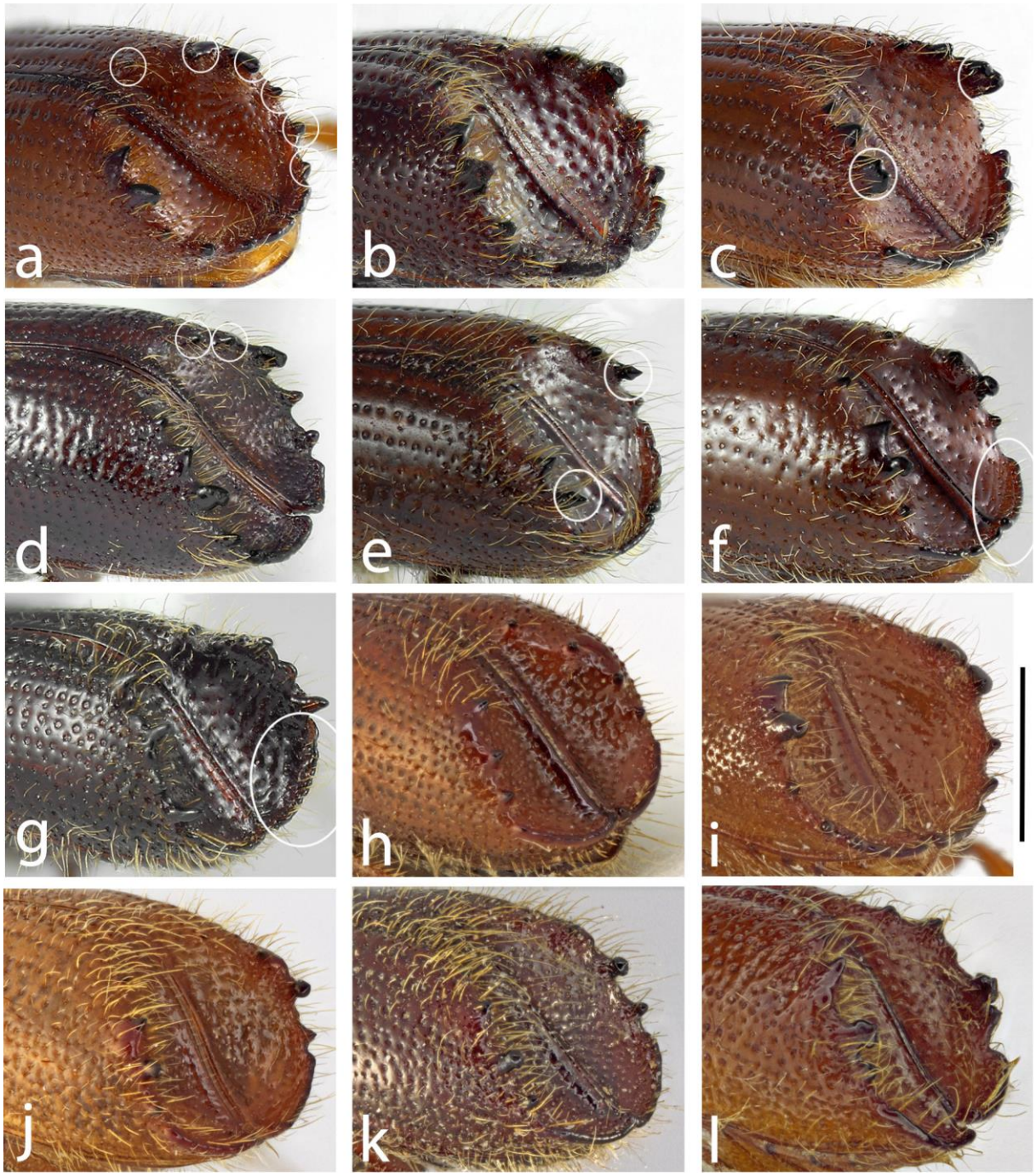

Figure 12. Elytral declivity of Ipini spp.: (a) *I. calligraphus* (six spines); (b) *I. grandicollis* (five spines); (c) *I. emarginatus* (bidentate third spine); (d) *I. montanus* (five spines); (e) *I. perturbatus* (third spine pedunculate and acute); (f) *I. tridens* (explanate apex of declivity); (g) *Orthotomicus latidens* (smaller explanation of apex of declivity); (h) *I. hauseri* (third spine tapered and acute); (i) *I. lecontei* (third spine hooked and obtuse); (j) *I. plastographus* (third spine pedunculate and subacute); (k) *I. subelongatus* (third spine pedunculate and subacute); (l) *I. cembrae* (third spine pedunculate and subacute). Scale bar: 1 mm.
Photos courtesy of (a to g) K. Bolte, Canadian Food Inspection Agency, Ottawa, Canada; (h to l) K. Savard, Agriculture and Agri-Food Canada, Ottawa, Canada.

Figure 13. (a)–(b) Elytral declivity of Ipini spp. showing relative distances between first spine and suture vs first and second spines: (a) *I. pini* (first spine closer to suture); (b) *Pseudips mexicanus* (first spine closer to second spine). Scale bar: 1 mm. (c)–(d) Elytral disc of Ipini spp. showing punctation of elytral intervals (between major strial rows of punctures): (c) *I. pini* (without punctures); (d) *Pseudips mexicanus* (punctate). Scale bar: 1.5 mm.
Photos courtesy of K. Bolte, Canadian Food Inspection Agency, Ottawa, Canada.

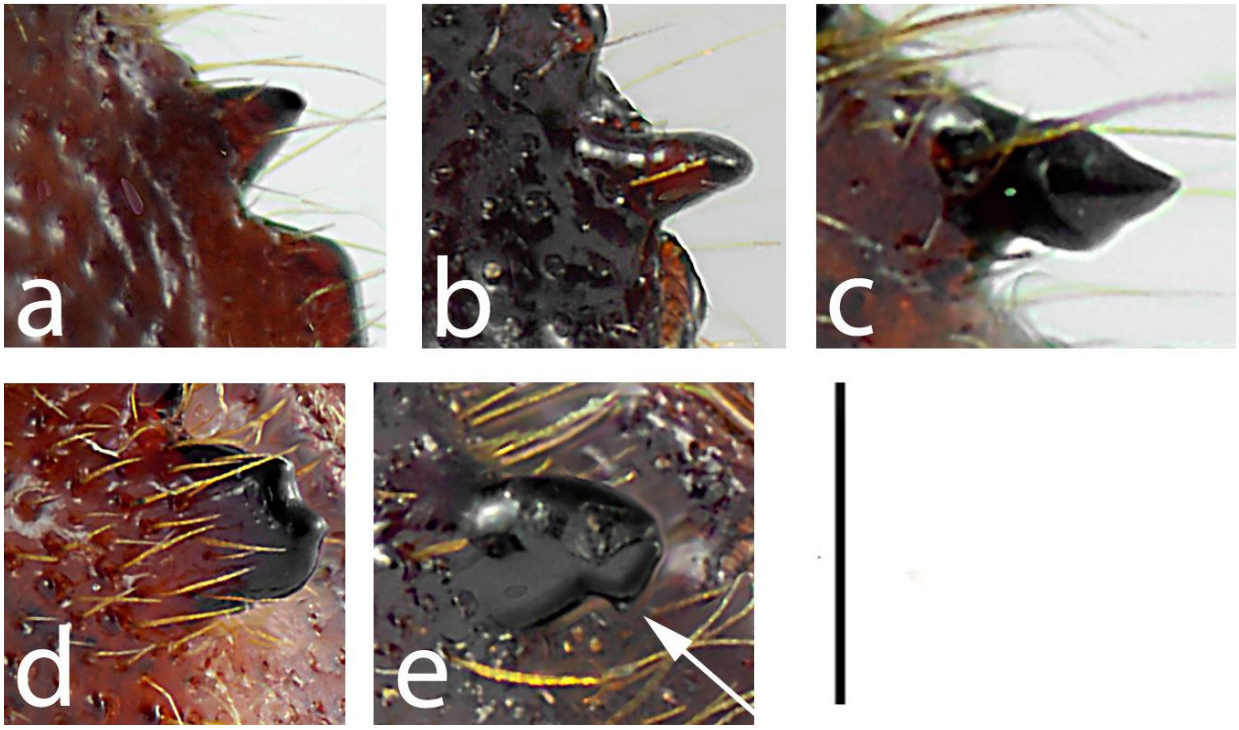

Figure 14. Shape of spines of elytral declivity of *Ips* spp.: (a) tapered; (b) straight-sided with tapered apex; (c) pedunculate (narrowed near base); (d) bidentate (two apices); (e) hooked (point on posterior edge shown with arrow). Scale bar: 0.5 mm.
Photos courtesy of K. Bolte, Canadian Food Inspection Agency, Ottawa, Canada.

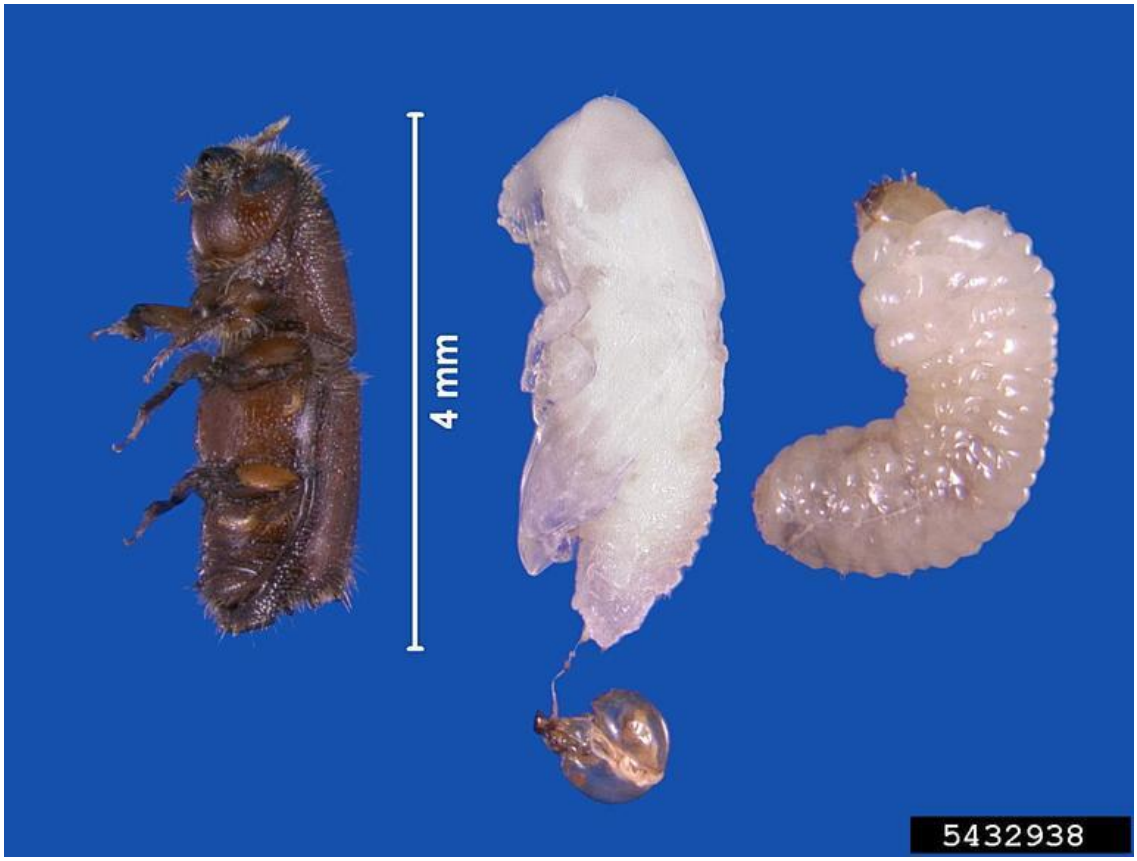

Figure 15. *Ips grandicollis*: from left to right, adult, pupa (with larval head capsule attached) and larva.
Source: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org.

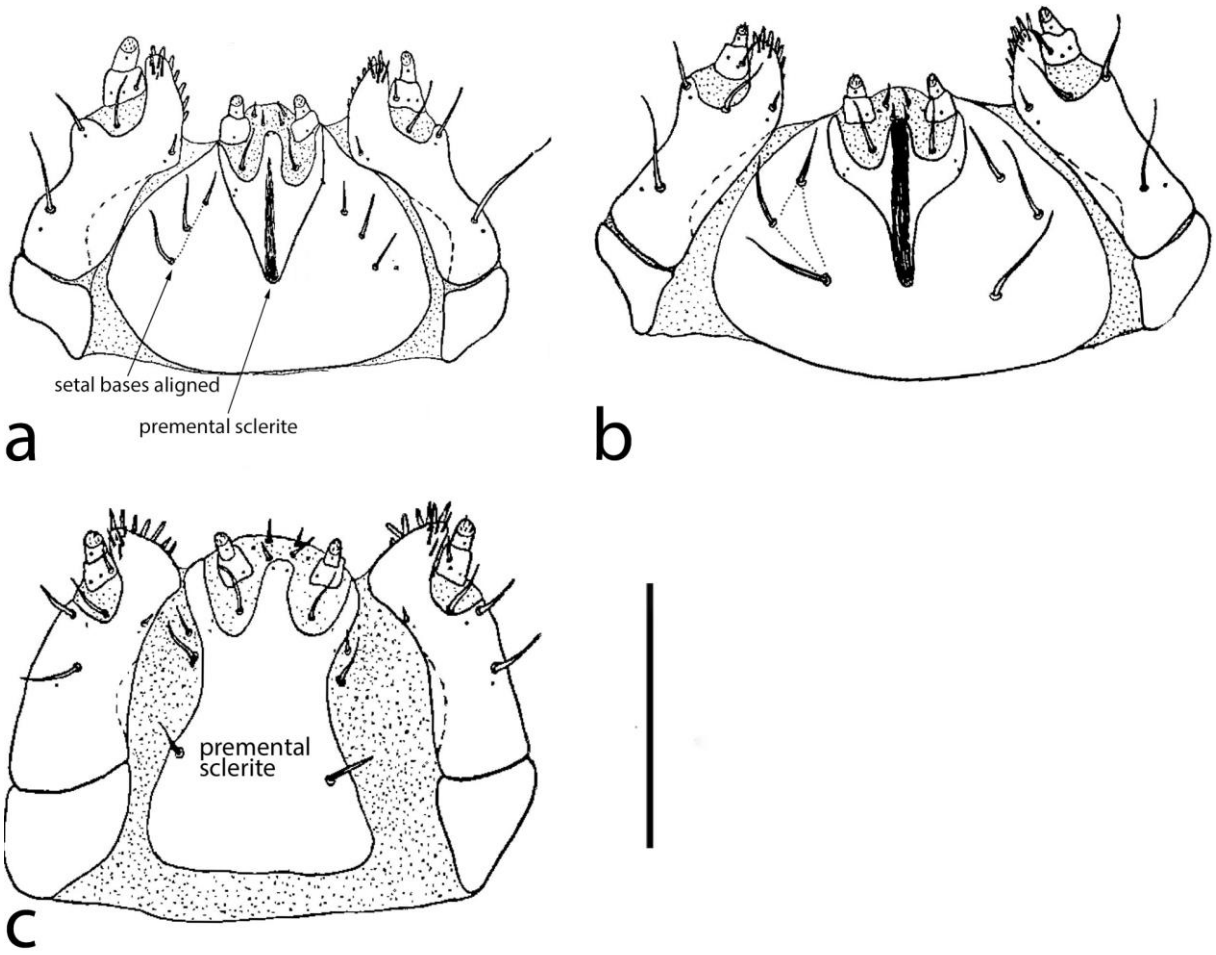

Figure 16. Scolytinae larvae, ventral view of mouthparts: (a) *Ips pini*, showing triangular premental sclerite and aligned postlabial setal bases; (b) *Polygraphus rufipennis* with postlabial setal bases arranged in triangle; (c) *Trypodendron lineatum* with premental sclerite rectangular. Scale bar: 0.5 mm.
Source: Thomas (1957).

Publication history
This is not an official part of the standard
2006-05 Standards Committee (SC) added original subject: *Ips spp.* (2006-020).
2016-12 Expert consultation.
2017-02 Technical Panel on Diagnostic Protocols (TPDP) reviewed.
2017-06 SC approved for consultation (2017_eSC_Nov_04).
2017-07 Consultation.
2017-10 Responses to comments from consultation completed.
2018-02 TPDP approved draft to submit to SC for approval for adoption.
2018-04 SC approved draft to be submitted to the 45-day DP notification period (2018_eSC_May_10)
2018-07 DP notification period (no objections received).
2018-08 SC adopted DP on behalf of CPM.
ISPM 27. Annex 27. *Ips* spp. (2018). Rome, IPPC, FAO.
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