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IBALIID PARASITOIDS OF SIRICID WOODWASPS IN NORTH AMERICA: TWO NEW *IBALIA* SPECIES AND A KEY TO SPECIES (HYMENOPTERA: CYNIPOIDEA)

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Abstract.—Two new parasitic wasp species, ***Ibalia kirki*** and ***Ibalia arizonica*** (Ibaliidae), are described from the northern Arizona-New Mexico region. Both species were found among preserved specimens reared from woodwasp-infested coniferous trees in 1971–72 during a search for natural enemies of Siricidae for introduction to Australia. The two new species belong to a monophyletic group of four species within *Ibalia* (*Ibalia*). Three of these species are known only from southwestern North America, whereas the fourth, *I. leucospoides* (Hochenwarth), is widely distributed throughout the Holarctic region. The phylogeny and the historical biogeography of this group of species is discussed briefly. North American distribution records of all six *I.* (*Ibalia*) species known from the region are mapped. A key to the North American *Ibalia* species is presented, including a representative of the subgenus *Tremibalia.*

Key Words: Hymenoptera, Cynipoidea, Ibaliidae, *Ibalia,* key, new species, Arizona, distribution N. America, Siricinae hosts

To control the accidentally introduced woodwasp *Sirex noctilio* F. on *Pinus radiata* D. Don in Australia, CSIRO made a worldwide search for natural enemies during 1962–1973 (Spradbery 1970, Kirk 1974, 1975, Taylor 1976, 1978, 1980, Spradbery and Kirk 1978, Madden 1988). Among the preserved woodwasp parasitoids collected by A. A. Kirk in northern Arizona-New Mexico (see Kirk 1975) we found two previously undescribed *Ibalia* species closely related to *Ibalia leucospoides* (Hochenwarth). Because these three species are similar in appearance, specimens of the two new species were previously assigned to belong to *I. leucospoides* by Kerrich (1973).

Ibalia leucospoides is widely distributed throughout Eurasia, northern Africa and North America (Kerrich 1973, Spradbery and Kirk 1978), whereas the two new species are known only from material labelled Arizona or Arizona-New Mexico. A fourth close relative, *I. ruficollis,* appears to be restricted to Arizona, New Mexico and northern Mexico. In total, we examined about 400 specimens of these four species. The specimens of *I. leucospoides* came from throughout the Holarctic region, including the southwestern United States. A number of morphometric measurements were collected, some of which were found useful in separating the species (Figs. 1–3). Surface sculpture and color also provided a number of distinguishing characters.

The family Ibaliidae includes the East Asian genus *Heteribalia* Sakagami and the

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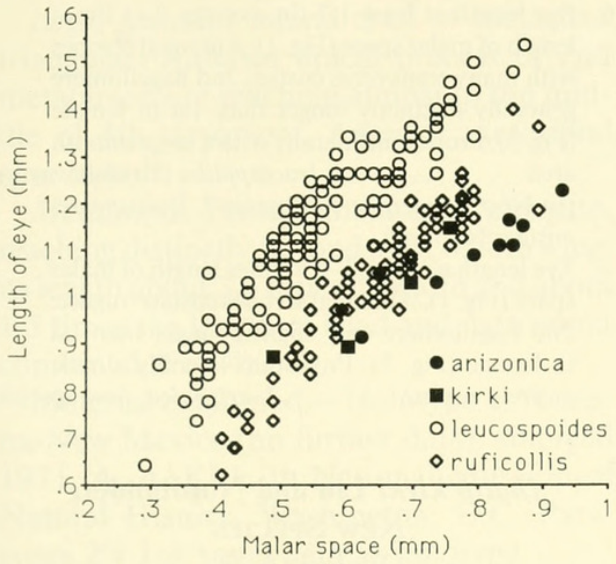


Fig. 1. Correlation between the length of the eye and the malar space in specimens of both sexes.

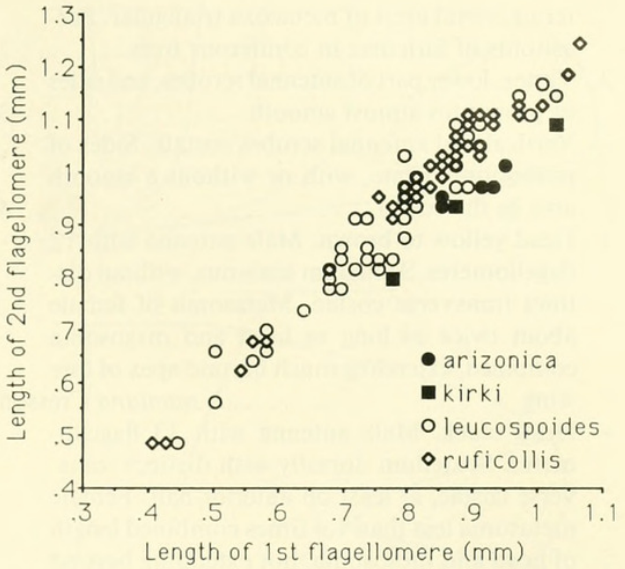


Fig. 3. Correlation between the lengths of the 2nd and the 1st flagellomere of the female antenna.

mainly Holarctic genus *Ibalia* Latreille, which is divided into the subgenera *Ibalia* and *Tremibalia* Kierych (Kierych 1973, Ronquist and Nordlander 1989). Species of *I.* (*Ibalia*) are all parasitoids of Siricinae in coniferous trees whereas species of *I.* (*Tremibalia*) appear to be restricted to Tremicinae hosts in hardwoods. In North America, as well as in the southwestern USA, there are now six known species of the subgenus *Ibalia.* These include *I. montana* Cresson, *I. rufipes* Cresson, and the four species mentioned above. In addition, there is one North American representative of the subgenus *Tremibalia, I.* (*T.*) *anceps* Say (see Ronquist and Nordlander 1989: 22), which is widely distributed east of the Rocky Mountains. The North American *Ibalia* species can be distinguished with the aid of the key presented below.

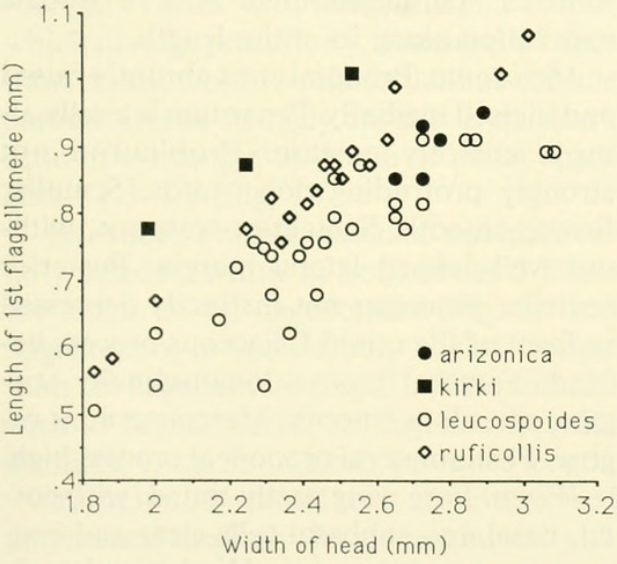


Fig. 2. Correlation between the length of the 1st flagellomere of the female antenna and the width of the head.

Structural terminology in the key and the species descriptions follow Ronquist and Nordlander (1989). Terms for wing cells are in accordance with Gauld and Bolton (1988). The characters mentioned in the species descriptions were selected among those that exhibit different states within the genus *Ibalia.* Illustrated and more detailed descriptions of other *Ibalia* species are presented in Kerrich (1973), Kierych (1973), and Ronquist and Nordlander (1989).

Key to the *Ibalia* species from North America

1. Eye length more than 3.0 times length of malar space. Male antenna with 12 flagellomeres. Hind wing with two hamuli. Anterior lateral crest of metacoxa rounded. Parasitoid of *Tremex columba* (L.) in hardwoods . . . *I. anceps* Say
– Eye length less than 2.7 times length of malar space (Fig. 1). Male antenna with 13 or (in *I. montana*) 12 flagellomeres. Three hamuli. An-

terior lateral crest of metacoxa triangular. Parasitoids of Siricinae in coniferous trees 2

2. Vertex, lower part of antennal scrobes, and sides of pronotum almost smooth 3
- Vertical and antennal scrobes costate. Sides of pronotum costate, with or without a smooth area in the center 4
3. Head yellow to brown. Male antenna with 12 flagellomeres. Scutellum scabrous, without distinct transverse costae. Metasoma of female about twice as long as head and mesosoma combined, extending much beyond apex of fore wing ..... *I. montana* Cresson
- Head black. Male antenna with 13 flagellomeres. Scutellum dorsally with distinct transverse costae, at least on anterior half. Female metasoma less than 1.4 times combined length of head and mesosoma, not extending beyond apex of fore wing ..... *I. rufipes* Cresson (In North America: subspecies *I. r. rufipes* (Cresson*)
4. Antennal scrobes with sparse oblique costae; carinae laterally delimiting antennal scrobes almost parallel. Width of head about 2.5 times length of 1st flagellomere in female (Fig. 2). Scutellum laterally without a distinct, smoothly curved marginal ridge. Posterior scutellar processes not distinctly depressed anterodorsally. Metasoma elongate (Fig. 4), its length in female more than 2.8 times its height and about 1.5 times combined length of head and mesosoma ..... **I. kirki**, new species
- Antennal scrobes with many transverse or irregular costae; lateral carinae at least slightly curved. Width of head at least 2.7 times the length of 1st flagellomere in female (Fig. 2). Scutellum laterally with a complete, smoothly curved ridge. Posterior scutellar processes distinctly depressed anterodorsally. Length of female metasoma less than 2.5 times its height and less than 1.4 times combined length of head and mesosoma (Fig. 5) 5
5. Pronotum largely reddish yellow (in extremely small specimens sometimes black with only a dark brown dot laterally). Fore wing smoky without contrasting clear areas (Fig. 6). Hind wing smoky except at base ... *I. ruficollis* Cameron
- Pronotum entirely black. Fore wing partly tinted, with costal, basal and subbasal cells clear and contrasting (Figs. 7, 8). Hind wing largely clear, tinted only along margin 6
6. Eye length at least 1.7 (in average 2.1) times length of malar space (Fig. 1). Antennal scrobes with many transverse costae. 2nd flagellomere generally distinctly longer than 1st in female (Fig. 3). Pronotum laterally with a large smooth area ..... *I. leucospoides* (Hochenwarth) (In North America: subspecies *I. leucospoides ensiger* Norton*)
- Eye length about 1.3–1.5 times length of malar space (Fig. 1). Antennal scrobes costate-rugose. 2nd flagellomere only slightly longer than 1st in female (Fig. 3). Pronotum laterally almost entirely costate ..... ***I. arizonica***, new species

* The Nearctic and Palearctic subspecies of both *I. rufipes* and *I. leucospoides* were recognized by Kerrich (1973) on the basis of differences in the coloration of the metasoma.

Ibalia kirki Liu and Nordlander, New Species

Figs. 1–4, 9

Head, antennae, mesosoma and legs black; metasoma reddish brown, without light patches.

Head: Vertex with many distinct costae, which diverge posteriorly. Antennal scrobes with sparse oblique costae; lateral carinae parallel. Genae strongly costate. Ratio of eye length to length of malar space about 1.5–1.8 (Fig. 1).

Antennae: Female antenna slender; width of head about 2.5 times the length of 1st flagellomere (Fig. 2). 2nd flagellomere in female only slightly longer than 1st flagellomere (Fig. 3). Male antenna with 13 flagellomeres; 1st flagellomere with a sinuate excavation along its entire length.

Mesosoma: Pronotal crest abruptly raised and incised medially. Pronotum laterally almost entirely costate. Propleuron not strongly protruding downwards. Scutellar foveae smooth. Scutellum scabrous; without well-defined lateral margin. Posterior scutellar processes not distinctly depressed in front of the raised foliaceous process behind. Femoral groove longitudinally strigate; speculum smooth. Metepisternum rugose. Posterolateral propodeal process high.

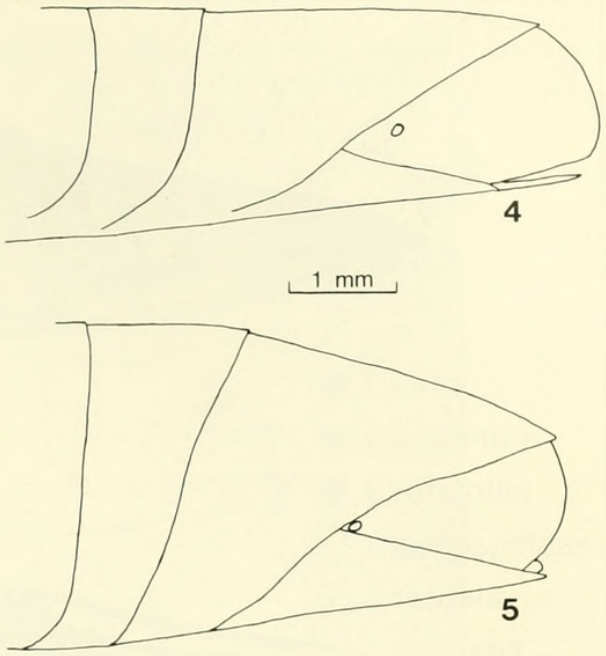
Wings: Fore wing partly tinted, with costal, basal and subbasal cells clear and contrasting. Areolet present. Hind wing largely tinted, clear at base. Three hamuli.

Legs: Anterior lateral crest of metacoxa triangular. Anterior apical process of 2nd metatarsomere reaching almost to the middle of 4th tarsomere. Anterior mesotibial spur absent.

Metasoma: Female metasoma elongate, reaching distinctly beyond apex of fore wing; its length about 3.1 times its width and about 1.5 times the length of head and mesosoma combined (Fig. 4).

Material examined.—Holotype ♀: Arizona-New Mexico (no further data), emerged 1971, A. A. Kirk, in National Museum of Natural History, Washington, D.C. Paratypes 2 ♀ 1 ♂: same data as holotype.

All specimens reared from siricid-infested coniferous material (Kirk 1975). (This may have been wood from dead, mature trees of *Picea engelmannii* Parry felled at an altitude above 2500 m on Mount Humphreys, Arizona, and containing *Sirex cyaneus* F. and *Xeris spectrum* L. [A. A. Kirk in litt.]).



Figs. 4–5. Posterior part of the female metasoma in lateral view. 4, *I. kirki.* 5, *I. arizonica.*

Ibalia arizonica Liu and Nordlander, New Species

Figs. 1–3, 5, 7, 9

Head, antennae, mesosoma and legs black; metasoma reddish brown, without light patches.

Head: Vertex with many distinct costae, which diverge posteriorly. Antennal scrobes transversely costate-rugose; lateral carinae curved. Genae strongly costate. Eyes short; ratio of eye length to length of malar space about 1.3–1.5 (Fig. 1).

Antennae: Female antenna not particularly slender; width of head about 3 times the length of 1st flagellomere (Fig. 2). 2nd flagellomere in female only slightly longer than 1st flagellomere (Fig. 3). Male antenna with 13 flagellomeres; 1st flagellomere with a sinuate excavation along its entire length.

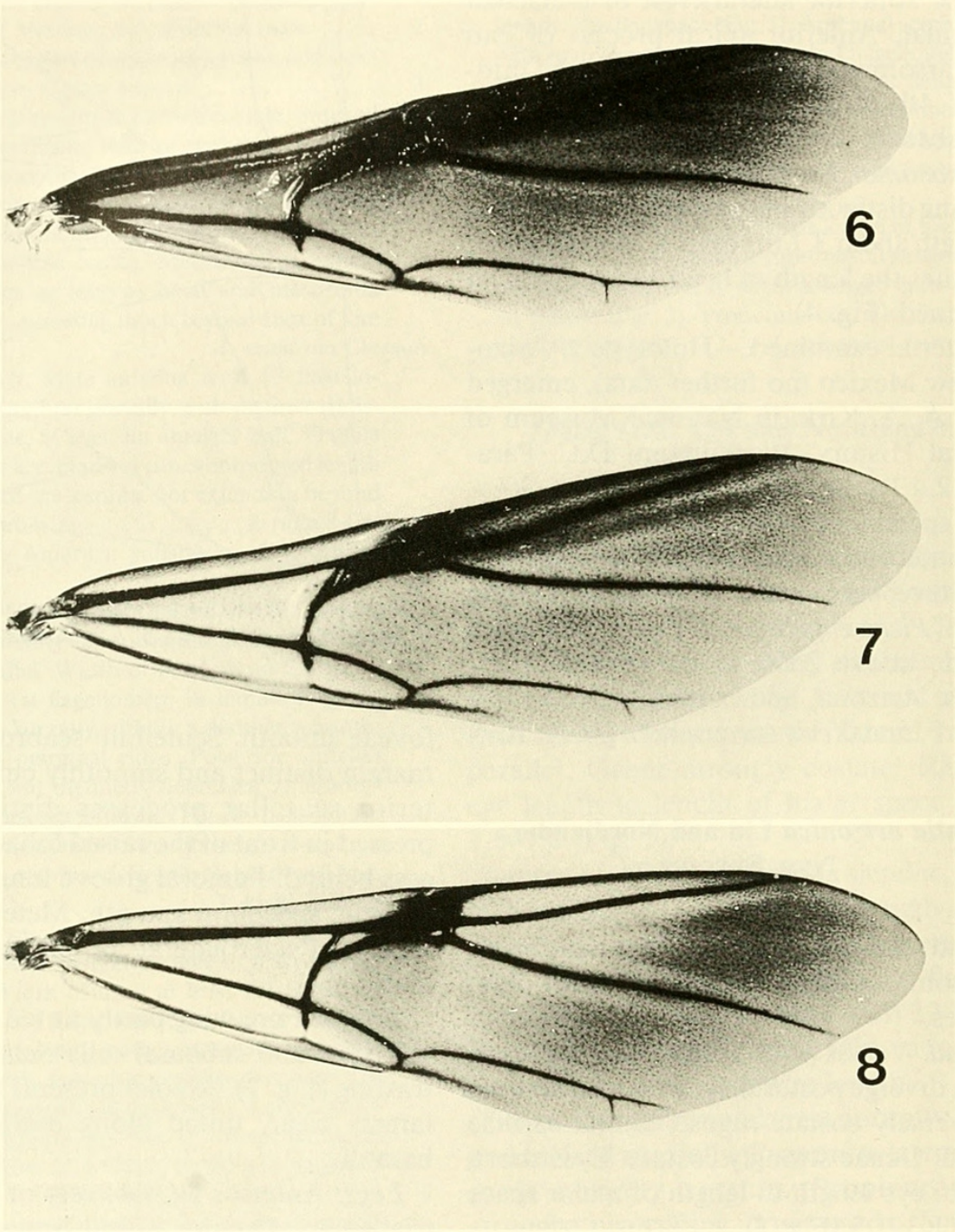
Mesosoma: Pronotal crest abruptly raised and incised medially. Pronotum laterally almost entirely costate. Propleuron not strongly protruding downwards. Scutellar foveae smooth. Scutellum scabrous; lateral margin distinct and smoothly curved. Posterior scutellar processes distinctly depressed in front of the raised foliaceous process behind. Femoral groove longitudinally strigate; speculum smooth. Metepisternum rugose. Posterolateral propodeal process high.

Wings: Fore wing partly tinted, with costal, basal and subbasal cells clear and contrasting (Fig. 7). Areolet present. Hind wing largely clear, tinted along margin. Three hamuli.

Legs: Anterior lateral crest of metacoxa triangular. Anterior apical process of 2nd metatarsomere reaching almost to the middle of 4th tarsomere. Anterior mesotibial spur absent.

Metasoma: Female metasoma not elongated; its length about 2.3 times its width and about 1.2 times the length of head and mesosoma combined (Fig. 5).

Material examined.—Holotype ♀: USA, Arizona-New Mexico (no further data), emerged 1972, A. A. Kirk, in National Museum of Natural History, Washington, D.C.



Figs. 6–8. Fore wing. 6, *I. ruficollis*. 7, *I. arizonica*. 8, *I. leucospoides ensiger*.

Paratypes 4 ♀ 3 ♂: 1 ♀ 3 ♂, same data as holotype; 2 ♀, Arizona, 1972, A. A. Kirk, in Natural History Museum, London; 1 ♀, Arizona, 1972, A. A. Kirk, in Australian National Insect Collection, Canberra.

All specimens reared from siricid-infested coniferous material (Kirk 1975); tree species and exact localities unknown.

Biogeography and Phylogenetic Relationships

Including the two species described here, the genus *Ibalia* comprises 12 species in the world, seven of which belong in the subgenus *Ibalia* (Ronquist and Nordlander 1989). Only one of the *I.* (*Ibalia*) species

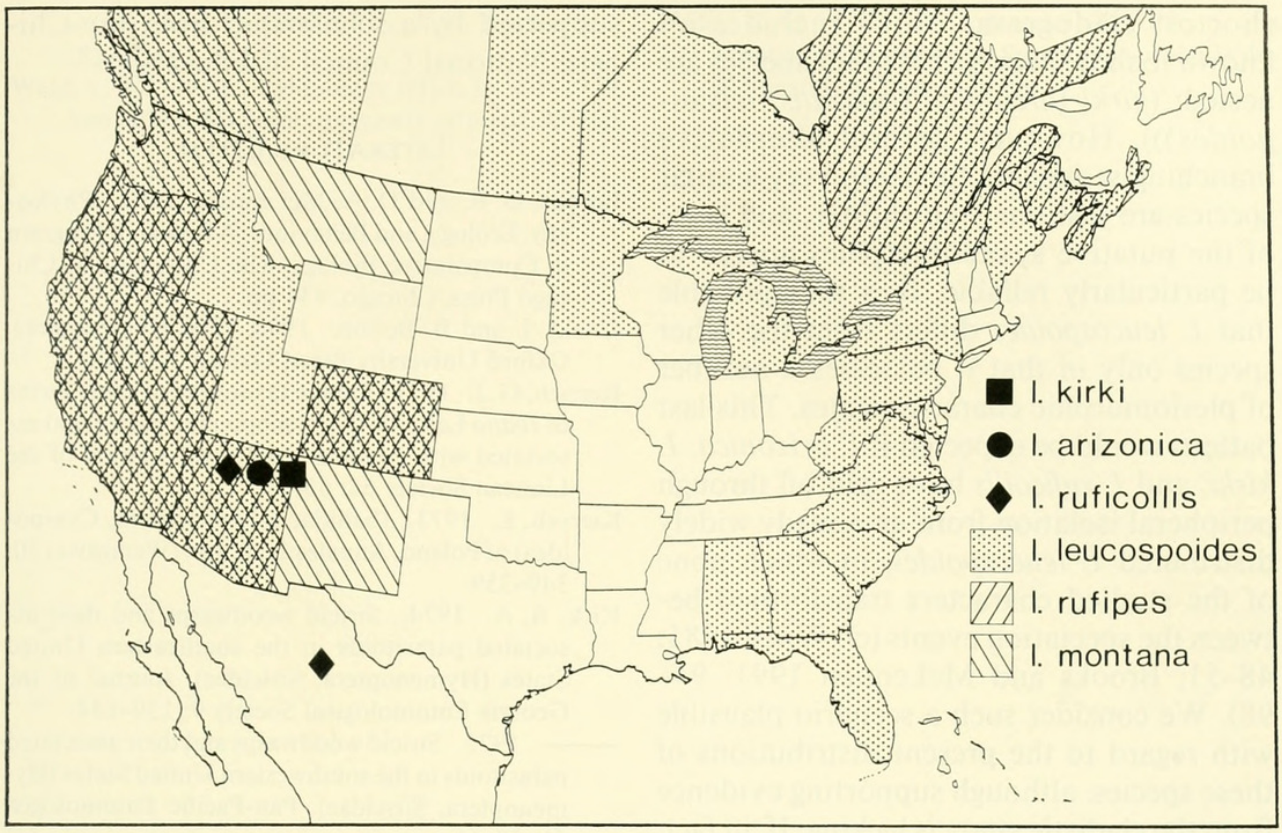


Fig. 9. Distributions of *Ibalia* (*Ibalia*) species in North America. The various types of hatching and the symbols indicate at least one record from a state or province. The map is based on examined material in the Australian National Collection, Canberra, the California Academy of Sciences, San Francisco, the Canadian National Collection, Ottawa, the Natural History Museum, London, and the U.S. National Museum, Washington, D.C. In addition, the following records from the literature are included: *I. leucospoides* from Alabama and South Carolina (Kirk 1974), *I. montana* from New Mexico (Kirk 1975), Montana and Oregon (Weld 1952) (Weld's record from Labrador needs confirmation and is therefore omitted), and *I. rufipes* from Colorado (Kirk 1975). Krombein et al. (1979) reported *I. rufipes* from Alberta, Manitoba, and Ontario, but these records probably refer to *I. gigantea* Yoshimoto, which they erroneously listed as a synonym of *I. rufipes* (Kerrich [1973] demonstrated that *I. gigantea* is a synonym of *I. leucospoides ensiger*). In addition to the records indicated on the map, one specimen of *I. leucospoides* was recorded from Northwestern Territories, Canada.

does not occur in North America; *I. aprilina* Kerrich from Japan. Figure 9 shows the known distributions of *I.* (*Ibalia*) species in North America. *Ibalia leucospoides* and *I. rufipes* are widely distributed throughout the Holarctic region. *Ibalia montana* occurs in mountainous areas in western North America, including the Rocky Mountains, Pacific Mountain System and Colorado Plateau, ranging from Arizona in the south to British Columbia in the north. The two new species *I. arizonica* and *I. kirki* are both known only from Arizona-New Mexico and the closely related *I. ruficollis* only from that area and the adjacent Chihuahua province in Mexico. *Ibalia leucospoides* appears to be infrequent in Arizona-New Mexico; only one male, from Happy Jack, Arizona, was found in the material we studied.

The quite restricted distributions of *I. arizonica, I. kirki* and *I. ruficollis* in southwestern North America suggest that they have speciated in this region. According to a forthcoming cladistic study of the family Ibaliidae (Nordlander, Liu, and Ronquist, manuscript), these species form together with *I. leucospoides* a monophyletic group within the subgenus *Ibalia.* In the single

shortest cladogram, which includes all known ibaliid species, these four species are nested: (*kirki* (*arizonica* (*ruficollis, leucospoides*))). However, several alternative branching sequences for these very similar species are just one step shorter, and none of the putative synapomorphies appear to be particularly reliable. It is thus possible that *I. leucospoides* differs from the other species only in that it possesses a number of plesiomorphic character states. This last pattern would be expected if *I. arizonica, I. kirki,* and *I. ruficollis* have split off through peripheral isolation from an already widely distributed *I. leucospoides,* in which none of the studied characters transformed between the speciation events (cf. Wiley 1981: 48–51; Brooks and McLennan 1991: 94–98). We consider such a scenario plausible with regard to the present distributions of these species, although supporting evidence from the cladistic study is lacking. If, in fact, *I. leucospoides* shares some true synapomorphies with only one or two of the other species, as implied in the shortest cladogram, character transformations must have occurred in their stem species. In that case *I. leucospoides* should either have spread over the world from southwestern North America after these speciation events, or the new character states must have had time between speciations to become established in the populations throughout the range of a widely distributed ancestor.

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Literature Cited

Brooks, D. R. and D. A. McLennan. 1991. Phylogeny, Ecology, and Behaviour. A Research Program in Comparative Biology. The University of Chicago Press, Chicago. 434 pp.

Gauld, I. and B. Bolton. 1988. The Hymenoptera. Oxford University Press, Oxford. 332 pp.

Kerrich, G. J. 1973. On the taxonomy of some forms of *Ibalia* Latreille (Hymenoptera: Cynipoidea) associated with conifers. Zoological Journal of the Linnean Society 53: 65–79.

Kierych, E. 1973. Ibaliidae (Hymenoptera, Cynipoidea) of Poland. Annales Zoologici (Warszawa) 30: 349–359.

Kirk, A. A. 1974. Siricid woodwasps and their associated parasitoids in the southeastern United States (Hymenoptera: Siricidae). Journal of the Georgia Entomological Society 9: 139–144.

———. 1975. Siricid woodwasps and their associated parasitoids in the southwestern United States (Hymenoptera: Siricidae). Pan-Pacific Entomologist 51: 57–61.

Krombein, K. V., P. D. Hurd, Jr., D. R. Smith, and B. D. Burks. 1979. Catalog of Hymenoptera in America North of Mexico, Volume 1. Smithsonian Institution Press, Washington, D.C.

Madden, J. L. 1988. *Sirex* in Australasia, pp. 407–429. *In* Berryman, A. A., ed., Dynamics of Forest Insect Populations. Plenum Press, New York.

Ronquist, F. and G. Nordlander. 1989. Skeletal morphology of an archaic cynipoid, *Ibalia rufipes* (Hymenoptera: Ibaliidae). Entomologica Scandinavica, Supplement 33: 1–60.

Spradbery, J. P. 1970. The biology of *Ibalia drewseni* Borries (Hymenoptera: Ibaliidae), a parasite of siricid woodwasps. Proceedings of the Royal Entomological Society of London (A) 45: 104–113.

Spradbery, J. P. and A. A. Kirk. 1978. Aspects of the ecology of siricid woodwasps (Hymenoptera: Siricidae) in Europe, North Africa and Turkey with special reference to the biological control of *Sirex noctilio* F. in Australia. Bulletin of Entomological Research 68: 341–359.

Taylor, K. L. 1976. The introduction and establishment of insect parasitoids to control *Sirex noctilio* in Australia. Entomophaga 21: 429–440.

———. 1978. Evaluation of the insect parasitoids of *Sirex noctilio* (Hymenoptera: Siricidae) in Tasmania. Oecologia (Berlin) 32: 1–10.

———. 1980. Studies with *Sirex noctilio* (hymenoptera: siricidae) and its parasites that illustrate the importance of evaluating biological control at-

tempts. Acta Oecologica/Oecologia Applicata 1: 181–187.

Weld, L. H. 1952. Cynipoidea (Hym.) 1905–1950. Ann Arbor, Michigan (privately printed). 351 pp.

Wiley, E. O. 1981. Phylogenetics. The Theory and Practice of Phylogenetic Systematics. John Wiley & Sons, New York. 439 pp.