CHAPTER 12-5
TERRESTRIAL INSECTS: HEMIMETABOLA – NOTOPTERA AND PSOCOPTERA

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Figure 1. Example of **Mantophasmatodea**, a subgroup of the **Notoptera**. Photo by Michael F. Schönitzer through Creative Commons.

NOTOPTERA

The order **Notoptera** perhaps deserves its own chapter simply because the smallest chapter is appropriate for the smallest order (<30 species) of insects (Ando & Machida 1987). But alas, for practical reasons, I have included the **Psocoptera** here as well, a much larger order but rare among bryophytes. The order **Notoptera** is poorly known and has limited, but widespread, distribution. Nevertheless, it is important in our understanding of insect evolution (Vrsansky *et al*. 2001). And mosses seem to play a role for at least some of their lives.

The order **Notoptera** is **relict** (survived from an earlier time period) (Vrsansky *et al*. 2001; Schoville & Kim 2011) and in addition to the two living families, it is known from fossils in middle Eocene (Lutetian) Baltic amber (Arillo & Engel 2006) and the Lower Permian (Aristov 2004), suggesting that it has been widespread in time and space. The living **Notoptera** are known only from Canada (Walker 1914), western United States (Caudell & King 1924; Kamp 1963, 1970), Russia (Bey-Bienko 1951; Kevan 1979), Korea (Storozhenko & Park 2002; Kim & Lee 2007), China (Wang 1987), and northern Japan (Schoville 2010). Genetic isolation in parts of Asia may have resulted from geologic events in which islands fragmented and collided, causing mountain uplifts in Japan (Schoville *et al*. 2013). The remaining taxa appear to be a "poorly dispersing, cold-adapted terrestrial insect lineage" that occupies Japan, Korea, and Russia. The island fragmentation events have created a number of endemic species. In the western US, several Grylloblattidae and **Gryllacrididae** returned to the devastated Mt. St. Helens within three years after its eruption in 1980 (Sugg & Edwards 1998), suggestion that it has some means of dispersal.

The order **Notoptera** was named in 1915 but was largely overlooked (Wikipedia 2016a). More recently, it was somewhat resurrected and joined with the Grylloblattodea, placing both of them in the order **Notoptera**.

These insects resemble mantids, but never have wings (Ando & Machida 1987). They live under stones and in

caves in the alpine areas (Schoville & Kim 2011). They are well adapted to cold conditions (Pritchard & Scholefield 1978; Kevan 1979; Jarvis & Whiting 2006). Many retreat deep below the surface to escape surface temperatures ranging -35 to +45°C (Kevan 1979).

Grylloblattodea – Ice Crawlers

The **Grylloblattodea** are predominately nocturnal and feed on detritus (Wikipedia 2015). They are wingless and have either reduced eyes or no eyes (Figure 2). There is only one family and it is comprised of only 5 genera and 34 species that live mostly in leaf litter and under stones of extremely cold environments of higher elevations.

Figure 2. Member of **Grylloblattidae** on snow, a small family that may lay eggs in mosses. Photo by Alex Wild through Creative Commons.

When temperatures are cold enough for ice crystals to form in the body, the **Grylloblattidae** retreat under the snow pack near the soil (Grimaldi & Engel 2005). They feed mostly on arthropod carcasses, but if these are insufficient they rely on plant material (Wikipedia 2015). At least one member deposits its eggs among mosses (Richards & Davies 1977).

Grylloblattidae – Ice Crawlers

The North American ice crawlers are known for their adaptations to cold, whereas the Asian members are the most diverse (Jarvis 2005; Jarvis & Whiting 2006). They are rarely encountered, but this may be due to their seclusive habit of going underground or hiding among mosses. Bai *et al*. (2010) suggested that they lost their wings and became adapted to living under rocks or hidden in mosses in cold areas.

Most members of this family are carrion feeders, but they will also eat plant material, fungi, and detritus (Bai *et al*. 2010).

The modern (extant) members of this family are 14-34 mm long, pale, wingless, and avoid light (nocturnal or living in caves) (Bai *et al*. 2010).

Galloisiana

Galloisiana nipponensis (Figure 3) was first described by Caudell and King in 1924 from Japan. This was the introduction of a new genus and new family, the **Grylloblattidae**. This species occurs on the ground under stones and in moss (Memim Encyclopedia 2015). To date, no eggs have been found among mosses in ***G. nipponensis*** (Rentz & Ingrisch 2009).

Figure 3. ***Galloisiana nipponensis***, an extant member of the **Notoptera** in northern Japan. Photo by Obsidian Soul through Creative Commons, with modified background.

Three quarters of a century later, ***Galloisiana olgae*** is a recently described species occurring in a small area on the banks of the Vasilkovka River in southeastern Russia (Vrsansky *et al*. 2001). The genus has also spread to Korea (Schoville & Kim 2011) and China (Wang 1987). It inhabits wet soil and is found under rocks that are covered with mosses. This raises an interesting question. What is the importance of the mosses on those rocks. I venture a guess. This and all members of the order are omnivores, often feeding on carcasses of other arthropods (Wikipedia 2015). Rocks with mosses provide easy access for these wingless insects to hunt for food among the mosses at night (or whenever they feed).

Grylloblatta

In North America, 13 species of ***Grylloblatta*** (Figure 4) have been described, but Schoville and Graening (2013) considered that another 16 are awaiting description and publication. Its known distribution in western North America (Caudell & King 1924) includes California, USA (Caudell 1923; Schoville & Roderick 2010; Schoville 2012), to British Columbia, Canada (Gregson 1938; Kamp 1979; Huggard & Klenner 2003). This is a genus with high endemism and small species ranges.

Bai *et al*. (2010) considered temperature to be the primary limiting factors in their distributions. This does not bode well for them in the face of global warming. A species of ***Grylloblatta*** (Figure 4) on Mt. Rainier, Washington, USA, is active on the snow in summer, where it forages at night (Edwards 1982). But they have behavioral strategies that enable them to avoid freezing, as seen in this ***Grylloblatta***. This species lacks the usual means to survive freezing (cryoprotectants, supercooling) and dies at a mere -6.5°C (Edwards 1987). On the other hand, it experiences heat convulsions at temperatures of 14°C. Morrissey and Edwards (1979) similarly found that the Mt. Rainier species suffers lethal heat convulsions at 15-20°C and speculated that unsaturated fatty acids might be important in their low-temperature adaptations. Could it

be that arachidonic acid, a polyunsaturated fatty acid in mosses, might contribute to this cold tolerance? Nevertheless, it migrates downward to overwinter among the rocks under deep snow where it is assured of temperatures above its -6.5°C lethal temperature (Edwards 1987). Henson (1957) was able to maintain nymphs of ***Grylloblatta campodeiformis*** (Figure 4) at 4.5°C for six months.

Figure 4. ***Grylloblatta campodeiformis***, a cold climate species that lays eggs on mosses. Photo through NSF public domain.

Huggard and Klenner (2003) collected 147 specimens of ***Grylloblatta campodeiformis*** (Figure 4) in British Columbia, Canada, in pitfall traps in the subalpine spruce-fir forest and lower elevation cedar-hemlock forest. Many were associated with mossy old-growth forests. They suggested that the moss layer was important for this species and that forest management practices might be reducing suitable habitat by affecting microclimate and snow accumulation – and moss cover.

When the female is about one year old, she will deposit black eggs singly among mosses or in soil (Kamp 1963, 1970; Ramel 2015). These eggs require another year to incubate, and the nymphal instars require about 5 years (8 instars) to become adults.

Grylloblatta campodeiformis (Figure 4) is a predaceous species that feeds on other arthropods (Pritchard & Scholefield 1978). Pritchard and Scholefield collected this species in the Rocky Mountains in Alberta, Canada at 1300 asl. Beamer (1933) found ***G. campodeiformis*** var. ***occidentalis*** in Mt. Baker in Washington.

The gut contents contained arthropods and little else, with a cranefly in the Tipulidae being the most common food. Both the ***Grylloblatta campodeiformis*** (Figure 4) and the tipulid are typical of cold, montane habitats. The ***G. campodeiformis*** eat only live or recently killed animal prey and both larvae and adults fail to develop or grow without animal food. To detect their prey, they use their antennae. Both the antennae and palpi (mouth parts) have sensitive hairs that most likely help in prey identification. The prey are seized by the mandibles.

I would expect to find some of them living among mosses or going there to feed because there are several species of cranefly larvae that live among the mosses. It could explain their association with the moss layer in old-growth forests. One cannot expect a wingless species to travel very far for food.

Members of ***Grylloblatta*** (Figure 4) possess **sensilla** (McIver & Sutcliffe 1982), a series of branched hairs protected by cuticle near the tip of the mandibles. Baker (1982) suggests they may be used to sense the pressure being exerted on the mandible tips, perhaps avoiding damage to the muscles.

Grylloblattella

Grylloblattella cheni was described as the second species in this genus, occurring in China (Bai *et al*. 2010). It is known from only one specimen, collected in the primary boreal coniferous forest near a lake. It was under the bark of a log near the summer snow line. This and other extant species have a shorter meso- and metathorax than prothorax, the opposite of the fossil species where the prothorax is shorter. They suggest this may be due to the loss of wings in the extant species.

PSOCOPTERA – Booklice, Barklice, Barkflies

This order is considered the most primitive of hemipteroids (Wikipedia 2016b). These are small insects(1-10 mm long). The barklice are harmless to the trees where they live, eating mostly algae and lichens. Their small size apparently makes scraping their food somewhat hazardous; their chewing mandibles are accompanied by a slender rod modified from the central lobe of the maxilla. This modified rod is used to brace them while they scrape their food with their mandibles. Some can spin silk, covering large areas of the bark (Hoell *et al*. 1998).

Most of the **Psocoptera** feed on detritus, epiphytes, fungi, and some on leaves (Baz 2008). They have a thin cuticle and thus are susceptible to desiccation. They are able to take up moisture from the atmosphere and obtain some of their water from food, but rarely by drinking.

Bryopsocus (**Bryopsocidae**) is associated with trees and mosses in wet forests (New & Lienhard 2007). This genus is endemic to New Zealand. Only two species occur there, both associated with mosses: ***Bryopsocus angulatus*** and ***B. townsendi***, ranging 2-3 mm long (Bess & Johnson 2009). Likewise in New Zealand, ***Echmepteryx madagascariensis*** (**Lepidopsocidae**; Figure 5) lives on mosses that grow on the horizontal trunks of ***Metrosideros*** (Figure 6) (Smithers 1973). Smithers (1974) also collected ***Spilopsocus avius*** (**Elipsocidae**) from mosses in the subAntarctic islands of New Zealand.

Figure 5. ***Echmepteryx madagascariensis***, a species that lives among mosses on horizontal trunks of ***Metrosideros***. Photo by Sean McCann through Creative Commons.

Figure 6. ***Metrosideros umbellata*** (rata) showing horizontal trunks with mosses where one might find ***Echmepteryx madagascariensis***. Photo by John Barkla, with permission.

Evidence of members of **Psocoptera** eating bryophytes is limited. Valle *et al*. (1977) reported one that feeds on mosses and lichens growing on citrus in Cuba.

Lucking (2000) pointed out that the **Psocoptera** are among the insects that feed on epiphyllous bryophytes, as well as other organisms (algae, fungi, lichens) that grow on the leaves. Unlike the **Lepidoptera** feeding there, the **Psocoptera** are generalists, eating whatever is available on the leaf. They typically lay their eggs on the lower leaf surfaces. The young juveniles are protected by their mothers. Lucking concluded that although they did considerable damage to the leaf habitat, they positively influenced the diversity of the lichen and bryophyte community.

Schmidt and New (2008) recorded other **Psocoptera** in association with mosses in Tasmania. ***Lepinotus patruelis*** (**Trogiidae**; Figure 7) was among mosses on a log; ***Liposcelis*** (**Liposcelidae**; Figure 8) occurs among mosses on logs and living trees.

Figure 7. ***Lepinotus patruelis***, a moss dweller on logs and trees in Tasmania. Photo from <www.aphotofauna.com>, with permission.

Figure 8. ***Liposcelis*** sp. hiding under bark. Photo by Peter J. Bryant, with permission.

Some members of this order are known from mossy forests, but the role of the mosses is unclear. García Aldrete (2009) reported several species from this habitat in Argentina: ***Polypsocus jujuyensis***, ***Polypsocus selenius*** (**Amphisocidae**), ***Lachesilla dividiproctus***, ***Lachesilla peckorum***, and ***Lachesilla cuala*** (**Lachesillidae**). On the other hand, Thornton (1985) found that the numbers and diversity of **Psocoptera** decreased on mountain tops with wet conditions and epiphytic mosses in many areas of the Pacific.

Some **Psocoptera** are restricted to caves. The **neotenous** (retaining juvenile characteristics in adults) ***Cyptophania pakaratii*** (Figure 9) seems to be limited to the fern-moss "gardens" in the cave entrances (Figure 10) in the Pacific basin (Mockford & Wynne 2013). These habitats serve as relict habitats of the last glacial maximum, supporting species that are restricted to the conditions they offer (Benedict 1979; Northup & Welbourn 1997; Wynne 2013; Wynne *et al*. 2014).

Figure 9. ***Cyptophania pakaratii***, a species apparently restricted to the fern-moss patches in cave entrances. Photo by Jut Wynne, with permission.

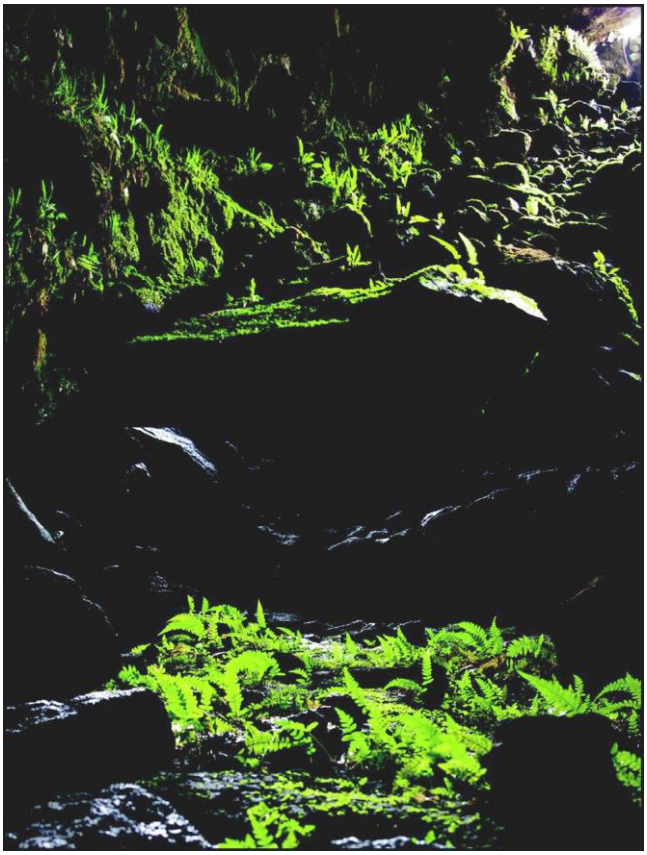

Figure 10. Relict fern-moss garden in cave at Rapa Nui National Park, Easter Island, Chile. Photo by Jut Wynne, with permission.

Summary

The **Notoptera** is a small order of relict insects, due in part to absence of wings and dispersal limitations. The **Grylloblattodea** (ice crawlers) are mostly nocturnal detritus feeders. Some can use mosses for oviposition. Members of **Grylloblattidae** may live under mosses in cold regions. ***Grylloblatta campodeiformis*** is often associated with mossy old-growth forests and deposits her eggs on the mosses.

Few species of **Psocoptera** are moss inhabitants, but their small size permits some of them to live there. The genus ***Bryopsocus*** is known only from mossy habitats in New Zealand. Some may feed on bryophytes, including epiphyllous bryophytes. Some are restricted to cave entrances where they live among mosses and ferns.

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Literature Cited

Ando, H. and Machida, R. 1987. Relationship between Notoptera and Dermaptera, from the embryological standpoint. In: Ando, H. and Jura, Cz. Recent Advances in Insect Embryology in Japan and Poland. Arthropod Embryol. Soc. Japan. ISEBU Co. Ltd., Tsukuba, Japan, pp. 151-157.

Arillo, A. and Engel, M. S. 2006. Rock crawlers in Baltic amber (Notoptera: Mantophasmatodea). Amer. Museum Novit. 3539: 1-10.

Aristov, D. S. 2004. The fauna of grylloblattid insects (Grylloblattida) of the Lower Permian locality of Tshekarda. Paleontol. J. 38(suppl 2): 80.

Bai, M., Jarvis, K., Wang, S.-Y., Song, K.-Q., Wang, Y.-P., Wang, Z.-L., Li, W. Z., Wang, W., and Yang, X.-K. 2010. A second new species of ice crawlers from China (Insecta: Grylloblattodea), with thorax evolution and the prediction of potential distribution. PLoS ONE 5(9): e12850.

Baker, G. T. 1982. Sensory receptors on the mandibles and labrum of *Grylloblatta campodeiformis* Walker. Zool. Anz. Jena 5: 341-344.

Baz, A. 2008. Bark-lice, book-lice or psocids (Psocoptera). In: Encyclopedia of Entomology. Springer Netherlands, pp. 381-399.

Beamer, R. H. 1933. Collecting *Grylloblatta campodeiformis* var. *occidentalis* Syl. Ann. Entomol. Soc. Amer. 26: 234-237.

Benedict, E. M. 1979. A new species of *Apochthonius* Chamberlin from Oregon (Pseudoscorpionida, Chthoniidae). J. Arachnol. 7: 79-83.

Bess, Emilie and Johnson, Kevin P. 2009. Bryopsocidae. *Bryopsocus*. Version 25 March 2009 in the Tree of Life Web Project. Accessed 17 June 2016 at <http://tolweb.org/Bryopsocus/30253>.

Bey-Bienko, G. Y. 1951. A new representative of Orthopteroid insect of the group Grylloblattoidea (Orthoptera) in the fauna of USSR. Ent. Obozr., Moscow [Entomol. Rev.] 31: 506-509.

Caudell, A. N. 1923. *Grylloblatta* in California. Can. Entomol. 55: 148-150.

Caudell, A. N. and King, J. L. 1924. A new genus and species of the notopterous family Grylloblattidae from Japan. Proc. Entomol. Soc. Wash. 26: 53-60.

Edwards, J. S. 1982. Habitat, behavior and neurobiology of an American grylloblattid. pp. 19-28. In: Ando, H. (ed.). Biology of the Notoptera. Kashiyo-Insatsu, Nagano, Japan. 194 pp.

Edwards, J. S. 1987. Arthropods of alpine Aeolian ecosystems. Ann. Rev. Entomol. 32: 163-179.

García Aldrete, A. N. 2009. New species and records of Psocoptera (Insecta) from Argentina. Zootaxa 2219: 1-17.

Gregson, J. D. 1938. *Grylloblatta campdeiformis* Walker – a new record. Can. Entomol. 60: 64-65.

Grimaldi, D. and Engel, M. S. 2005. Polyneoptera: Grylloblattodea: The Ice Crawlers. In: Evolution of the Insects. Cambridge University Press, N. Y., pp. 222-224.

Henson, W. R. 1957. Temperature preference of *Grylloblatta campodeiformis* Walker. Nature 179: 637.

Hoell, H. V., Doyen, J. T., and Purcell, A. H. 1998. Introduction to Insect Biology and Diversity, 2nd ed. Oxford University Press, Oxford, pp. 404-406.

Huggard, D. J. and Klenner, W. 2003. Grylloblattids in managed forests of south-central British Columbia. Northw. Sci. 77: 12-18.

Jarvis, K. J. 2005. Phylogeny and biogeography of ice crawlers (Insecta: Grylloblattodea): Evidence from six molecular loci. M. S. Thesis, Brigham University, Provo, Utah. <http://hdl.lib.byu.edu/1877/etd866>.

Jarvis, K. J. and Whiting, M. F. 2006. Phylogeny and biogeography of ice crawlers (Insecta: Grylloblattodea) based on six molecular loci: Designating conservation status for Grylloblattodea species. Molec. Phylogen. Evol. 41: 222-237.

Kamp, J. W. 1963. Descriptions of two new species of Grylloblattidae and of the adult of *Grylloblatta barberi*, with an interpretation of their geographical distribution. Ann. Entomol. Soc. Amer. 56: 53-68.

Kamp, J. W. 1970. The cavernicolous Grylloblattodea of the western United States. Ann. Speleol. 25: 223-230.

Kamp, J. W. 1979. Taxonomy, distribution, and zoogeographic evolution of *Grylloblatta* in Canada (Insecta: Notoptera). Can. Entomol. 111: 27-38.

Kevan, D. 1979. Notoptera. Mem. Entomol. Soc. Can. 111: 316-317.

Kim, B.-W. and Lee, W. 2007. A new species of the genus *Galloisiana* (Grylloblattodea, Grylloblattidae) from Korea. Zool. Sci. 24: 733-745.

Lucking, Robert. 2000. Biological Interactions in the Phyllosphere. Accessed 12 August at <http://www.old.uni-bayreuth.de/departments/planta2/ass/robert/lichens/phyllosphere.html>

McIver, S. B. and Sutcliffe, J. F. 1982. Sensilla of *Grylloblatta campodeiformis*. In: Ando, H. (ed.). Biology of the Notoptera. Kashiyo-Insatsu Co. Ltd., Nagano, Japan, pp. 137-157.

Memim Encyclopedia. 2015. Grylloblattidae: *Galloisiana nipponensis*. Accessed 9 October 2015 at <http://memim.com/grylloblattidae.html>.

Mockford, E. L. and Wynne, J. J. 2013. Genus *Cyptophania* Banks (Psocodea: 'Psocoptera': Lepidopsocidae): Unique features, augmented description of the generotype, and descriptions of three new species. Zootaxa 3702: 437-449.

Morrissey, R. and Edwards, J. S. 1979. Neural function in an alpine grylloblattid: A comparison with the house cricket *Acheta domesticus*. Physiol. Entomol. 4: 241-250.

New, T. and Lienhard, C. 2007. The Psocoptera of Tropical South East Asia. Fauna Malesiana Handbook Vol. 6. Brill, Leiden, The Netherlands.

Northup, D. E. and Welbourn, W. C. 1997. Life in the twilight zone – lava tube ecology, natural history of El Malpais National Monument. N. Mex. Bur. Mines Mineral Res. Bull. 156: 69-82.

Pritchard, G. and Scholefield, P. 1978. Observations on the food, feeding behaviour, and associated sense organs of *Grylloblatta campodeiformis* (Grylloblattodea). Can. Entomol. 110: 205-212.

Ramel, Gordon. 2015. Ice Bugs (Grylloblattodea). Accessed 9 October 2015 at <http://www.earthlife.net/insects/grryllobl.html>.

Rentz, D. C. F. and Ingrisch, S. 2009. Grylloblattodea (rock crawlers, ice crawlers). In: Resh, V. H. and Cardé, R. T. (eds.). Encyclopedia of Insects. 2nd edn. Academic Press, New York, Amsterdam, and others, pp. 434-435.

Richards, O. W., and Davies, R. G. 1977. "Grylloblattodea." Imms' General Textbook of Entomology. Springer Netherlands, p. 533.

Schmidt, E. R. and New, T. R. 2008. The Psocoptera (Insecta) of Tasmania, Australia. Mem Museum Victoria 65: 71-152.

Schoville, S. D. 2010. Natural history and biogeography of Grylloblattodea in Japan and North America. New Entomol. 59: 1-7.

Schoville, S. D. 2012. Three new species of *Grylloblatta* Walker (Insecta: Grylloblattodea: Grylloblattidae), from southern Oregon and northern California. Zootaxa 3412: 42-52.

Schoville, S. D. and Graening, G. O. 2013. Updated checklist of the ice-crawlers (Insecta: Grylloblattodea: Grylloblattidae) of North America, with notes on their natural history, biogeography and conservation. Zootaxa 3737: 351-378. <http://dx.doi.org/10.11646/zootaxa.3737.4.2>.

Schoville, S. D. and Kim, B.-W. 2011. Phylogenetic relationships and relictualism of rock-crawlers (Grylloblattodea: Grylloblattidae) in cave and mountain habitats of Korea. Ann. Entomol. Soc. Amer. 104: 337-347.

Schoville, S. D. and Roderick, G. K. 2010. Evolutionary diversification of cryophilic *Grylloblatta* species (Grylloblattodea: Grylloblattidae) in alpine habitats of California. BMC Evol. Biol. 10: 163.

Schoville, S. D., Uchifune, T., and Machida, R. 2013. Colliding fragment islands transport independent lineages of endemic rock-crawlers (Grylloblattodea: Grylloblattidae) in the Japanese archipelago. Molec. Phylogenet. Evol. 66: 915-927.

Smithers, C. N. 1973. A new species and new records of Psocoptera from the Kermadec Islands. N. Z. Entomol. 5: 147-150.

Smithers, C. N. 1974. Arthropoda of the subantarctic islands of New Zealand (4) Psocoptera. J. Royal Soc. N. Z. 4: 315-318.

Storozhenko, S. Y. and Park, J. K. 2002. A new genus of the ice crawlers (Grylloblattida: Grylloblattidae) from Korea. Far Eastern Entomol. 114: 18-20.

Sugg, P. M. and Edwards, J. S. 1998. Pioneer Aeolian community development on pyroclastic flows after the eruption of Mount St. Helens, Washington, U.S.A. Arct. Alp. Res. 30: 400-407.

Thornton, I. W. 1985. The geographical and ecological distribution of arboreal Psocoptera. Ann. Rev. Entomol. 30: 175-196.

Valle, N. D., Perez, F., and Grillo, H. 1977. [Presence of a moss-and-lichen eating Psocoptera on citrus in Jaguey Grande [Cuba]]. In: 5. National Meeting of Researches on Citrus and Other Fruits, Matanzas (Cuba), Apr 1977. Estacion Central de Investigaciones de Citricos y Otros Frutales.

Vrsansky, P., Storozhenko, S. Y., Labandeira, C. C., and Ihringova, P. 2001. *Galloisiana olgae* sp. nov. (Grylloblattodea: Grylloblattidae) and the paleobiology of a relict order of insects. Ann. Entomol. Soc. Amer. 94: 179-184.

Walker, E. M. 1914. A new species of Orthoptera forming a new genus and family. Can. Entomol. 46: 93-99.

Wang, S. Y. 1987. The discovery of Grylloblattodea in China and the description of a new species. Acta Entomol. Sinica 30: 423-429.

Wikipedia. 2015. Grylloblattidae. Accessed 3 July 2015 at <https://en.wikipedia.org/wiki/Grylloblattidae>.

Wikipedia. 2016a. Notoptera. Accessed 17 June 2016 at <https://en.wikipedia.org/wiki/Notoptera>.

Wikipedia. 2016b. Psocoptera. Accessed 25 January 2016 at <https://en.wikipedia.org/wiki/Psocoptera>.

Wynne, J. J. 2013. Conservation and management of lava tube caves at El Malpais National Monument. Park Sci. 30: 45-55.

Wynne, J. J., Bernard, E. C., Howarth, F. G., Sommer, S., Soto-Adames, F. N., Taiti, S., Mockford, E. L., Horrocks, M., Pakarati, L., and Pakarati-Hotus, V. 2014. Disturbance relicts in a rapidly changing world: The Rapa Nui (Easter Island) factor. BioScience 64: 711‑718.