Short Communication

Aphids and scale insects on threatened trees: co-extinction is a minor threat

Jonathan I. Thacker, Graham W. Hopkins and Anthony F.G. Dixon

Abstract Co-extinction is the extinction of a species following the extinction of another species that it used as a resource, such as a food plant in the case of insect herbivores. The magnitude of the global co-extinction threat to two herbivorous insect taxa (aphids and scale insects) was estimated by compiling a list of species in these groups that are dependent on globally threatened trees. Eleven species of aphid (0.69%) and thirteen scale insects (1.15%) have a threatened tree as their sole host. This measure is comparable to recent estimates for insect herbivores, but far less than the published overall estimates of extinction risk for invertebrates, and highlights the dependence of insect herbivores on a wide range of habitat features.

Keywords Aphids, co-extinction, scale insects, threatened trees.

The extinction of one species will inevitably result in the extinction of any other species that is specifically dependent upon it as a resource. For example, if a parasite has only one host species, then if the host goes extinct the parasite's extinction is inevitable. This phenomenon was termed co-extinction (Stork & Lyal, 1993) but can also affect host-specific natural enemies or mutualists (Bond, 1995; Shaw & Hochberg, 2001), including herbivores (Koh *et al.*, 2004b).

There are some high profile examples of insect herbivores threatened by co-extinction such as Fender's blue butterfly *Icaricia icarioides fenderi*, which uses the threatened Kincaid's lupine *Lupinus sulphureus kincaidii* as a foodplant (Schultz, 2001), and the Hawaiian fauna (Howarth & Ramsay, 1991). A list of British insects that are specific to rare plants and are known, or predicted, to be of conservation concern is given by Hopkins *et al*. (2002). Koh *et al.* (2004a) present estimates of co-extinction risk for a range of taxa.

If co-extinction is common within herbivore-plant associations then this phenomenon has the potential to be a major threat to biodiversity. For example, there may be between 2 and 10 million species of insect (Odegaard, 2000; Dolphin & Quicke, 2001), of which 46% are herbivores (Strong *et al*., 1984), with 22–47% of plant species threatened with extinction (Pitman & Jorgensen, 2002).

The objectives of this study are to estimate the magnitude of the co-extinction threat to insect herbivores by compiling a list of aphids and scale insects that are restricted to threatened trees. This list is the first attempt to identify aphids and scale insects that are likely to be globally threatened in this way.

Aphids and scale insects are small sap-sucking Homoptera that spend their entire life-cycle on their host plants, except when they are actively dispersing. Data on the host use of tree aphids (Hemiptera: Aphididae) were taken from *Aphids on the World's Trees* (Blackman & Eastop, 1994). Data on the host use of three families of scale insect (Hemiptera: Coccoidea) were taken from checklists that included host plant information (Ben-Dov, 1993, 1994). Host use data for aphids and scale insects are thought to be relatively reliable, even for tropical regions, because both groups contain pest species of shrubs and trees and have been the subject of extensive taxonomic studies (Green, 1909). From this list of host-specific scale insects the non-tree species were removed, using our personal knowledge and with reference to internet databases (e.g. A.C.G., 2002). The lists of trees were cross-referenced against *The World List of Threatened Trees* (Oldfield *et al*., 1998), and current statuses were confirmed on the IUCN Red List (IUCN, 2004). Host-alternating species were included if part of the life cycle includes a specific tree. Although only host-specific species were included here the number of species with more than one host, all of which are threatened, is thought to be low in the studied taxa.

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A number of trees are included in Oldfield *et al*. (1998) because the natural populations are threatened even though the trees are widely planted elsewhere. These trees were included in our analysis if the aphid or scale insect is thought to be restricted to the tree's native range; e.g. the monkey puzzle *Araucaria araucana*, which is native to Chile and Argentina where it has a specific scale insect.

Of 1,595 species of tree aphids, 11 (0.69%) are restricted to threatened trees, and of 1,133 tree-feeding scale insects that were identified, 13 (1.15%) are restricted to threatened trees. The 11 species of aphid are distributed among nine species of tree (Table 1). One of these, *Quercus dumosa*, is categorized as Endangered, facing a high risk of extinction in the wild, and is host to the aphid *Tuberculatus passalus*. Four trees, with six aphids, are categorized as Vulnerable, i.e. facing a high risk of extinction in the wild in the medium-term future.

The 13 species of scale insects are distributed among 10 species of tree (Table 2). One host, *Pandanus microcarpus*, is categorized as Critically Endangered, with <50 individuals surviving in the wild. The associated scale insect, *Mascarenococcus pandani*, may therefore already be extinct. Five trees, with six scale insects, are Vulnerable. Three species of tree, with five scale insects, are Lower Risk: near threatened.

Clearly this co-extinction estimate represents only a small proportion of the herbivores that are likely to be threatened, estimated at 25% by McKinney (1999), for at least two reasons. Firstly, some rare insects have demanding requirements (Thomas *et al*., 2001) or particularly common hosts (Dixon, 1998; Hopkins *et al*., 1998; Hopkins & Thacker, 1999; Hopkins *et al*., 2002). Secondly, extinction may occur before the complete loss of a host. Consequently, even if plant extinction is the primary threat to an insect species, the extinction of the herbivore may occur before the plant is recognized as being threatened. In Britain insect rarity is a continuous function of host plant rarity (Hopkins *et al*., 2002) but it is not clear how rare a host must be before this is the most important threat to the insect.

It is difficult to assess the applicability of our estimate of co-extinction threat. Taxa with the highest proportions of species at risk of co-extinction are those whose traits reduce their ability to find rare hosts (c.f. Dixon *et al*., 1987), and where monophagy on rare hosts is high. Compared to butterflies, for example, aphids certainly have lower host-finding abilities but are less likely to have evolved specificity to rare host species (Dixon, 1998). It is therefore difficult to assess whether other taxa are more or less prone to co-extinction, although the estimates here are broadly similar to those of 0.4% and 0.8% for beetles and butterflies, respectively (Koh *et al*., 2004a).

Co-extinction *per se* appears to be a relatively minor threat to aphids and scale insects, although it may be important for some species. It is evident that effective conservation of insects needs to be undertaken at the habitat level, where the maintenance of plant diversity is one component of habitat conservation.

Table 1 Threatened aphids and their distributions, their host tree species, and the trees' Red List status (IUCN, 2004), distribution and the factors threatening them with extinction.

Aphid	Aphid distribution	Host tree	Red List status[1]	Tree distribution	Threat
Tuberculatus passalus	USA	*Quercus dumosa*	EN	Mexico, USA	Habitat loss
Prociphilus formosanus	Taiwan	*Picea morrisonicola*	VU	Taiwan	Exploitation
Cinara anzai	USA	*Pinus albicaulis*	VU	Canada, USA	Habitat loss
Cinara inscripta	USA, Canada				
Cinara oregoni	USA, Canada				
Neophyllaphis podocarpini	Chile	*Podocarpus salignus*	VU	Chile	Exploitation, habitat loss
Sinonipponaphis hispida	Java	*Lithocarpus indutus*	VU	Indonesia	Few, small populations
Aulacorthum cercidiphylli	Japan	*Cercidiphyllum japonicum*	LR: nt	China, Japan, Taiwan	Poor regeneration
Thoracaphis sp.	Japan	*Cinnamomum japonicum*	LR: nt	China, Japan, Korea	Habitat loss
Cinara keteleeriae	China	*Keteleeria fortunei*	LR: nt	China, Viet Nam	Not stated
Byrsocryptoides zelkovaecola	Georgia	*Zelkova carpinifolia*	LR: nt	Armenia, Azerbaijan, Georgia, Iran, Turkey	Not stated

[1]EN, Endangered; VU, Vulnerable; LR: nt, Lower Risk: near threatened (IUCN, 1994, 2001)

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Table 2 Threatened scale insects and their distribution, their host tree species, and the trees' Red List status (IUCN, 2004), distribution and the factors threatening them with extinction.

Scale insect	Scale insect distribution	Host tree	Red List status[1]	Tree distribution	Threat
Mascarenococcus pandani	Mauritius	*Pandanus microcarpus*	CR	Mauritius	Invasive alien species
Chileputo chilensis	Chile	*Araucaria araucana*	VU	Argentina, Chile	Exploitation
Neoplatylecanium tripartitum	Sri Lanka	*Calophyllum walkeri*	VU	Sri Lanka	Few, small populations
Paralecanium mancum	Sri Lanka				
Richardiella taiensis	Ivory Coast	*Gilbertiodendron splendidum*	VU	West Africa	Habitat loss
Lachnodiopsis humboldtiae	Sri Lanka	*Humboldtia laurifolia*	VU	India, Sri Lanka	Few, small populations
Udinia ikoyensis	Gabon	*Khaya ivorensis*	VU	West Africa	Exploitation
Ceroplastes hawanus	Solomon Islands	*Barringtonia asiatica*	LR: lc	Tropical coasts of Indian & western Pacific Oceans	Not stated
Dysmicoccus amnicola	Papua New Guinea	*Araucaria hunsteinii*	LR: nt	Papua New Guinea	Exploitation
Pseudococcus linearis	Papua New Guinea				
Pulvinaria katsurae	Japan	*Cercidiphyllum japonicum*	LR: nt	China, Japan	Poor regeneration
Ceroplastes hempeli	Argentina	*Ilex paraguariensis*	LR: nt	South America	Exploitation
Pulvinaria paranaensis	Brazil				

[1]CR, Critically Endangered; VU, Vulnerable; LR: nt, Lower Risk: near threatened; LR: lc, Lower Risk: Least concern (IUCN, 1994, 2001)

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