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A new subspecies of *Neolucia hobartensis* (Miskin, 1890) (Lepidoptera: Lycaenidae) from Mainland Southeastern Australia, with a Review of Butterfly Endemism in Montane Areas in this Region

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Abstract. *Neolucia hobartensis albolineata* ssp. nov. is illustrated, diagnosed, described and compared with the nominate subspecies *N. hobartensis hobartensis* (Miskin, 1890) from Tasmania and *N. hobartensis monticola* Waterhouse & Lyell, 1914 from northern New South Wales, Australia. The new subspecies is restricted to montane areas (mainly >1000 m) in subalpine and alpine habitats on the mainland in southeastern Australia (southern NSW, ACT, VIC) where its larvae specialize on *Epacris* spp. (Ericaceae). It thus belongs to a distinct set of 22 butterfly taxa that are endemic and narrowly restricted to montane areas (>600 m, but mainly >900 m) on the tablelands and plateaus of mainland southeastern Australia. Monitoring of these taxa, including *N. hobartensis* ssp., is urgently required to assess the extent to which global climate change, particularly temperature rise and large-scale fire regimes, are key threatening processes.

Keywords. Butterfly conservation; climate change; key threatening processes; Polyommatinae; taxonomy

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The lycaenid genus *Neolucia* Waterhouse & R.E. Turner, 1905 comprises three species all endemic to southern Australia (Braby, 2000). It is currently placed in the subfamily Polyommatinae, a large polyphyletic assemblage nested within the Theclinae (Espeland *et al.*, 2018). Within this group, *Neolucia* is morphologically distinct with no close relatives (Hirowatari, 1992): the dorsal surface of the wings are uniformly dark bronze-brown, the egg is truncate dorsally with three prominent horizontal series of projections, and the larvae feed mainly on Ericaceae (with one species on Fabaceae) and are usually not attended by ants. *Neolucia hobartensis* (Miskin, 1890), commonly known as the 'Montane Heath-blue', is a polytypic species endemic to southeastern mainland Australia and Tasmania

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(Couchman & Couchman, 1977; Virtue & McQuillan, 1994; Braby, 2000; Field, 2013; Bond, 2016). All species of *Neolucia* occur in montane areas, but *N. hobartensis* is the only species restricted to high altitudes. Indeed, it is one of very few species of butterflies in Australia endemic to subalpine and alpine habitats (i.e. above the tree-line).

Two subspecies of *N. hobartensis* have been recognized: the nominate subspecies *N. hobartensis hobartensis* (Miskin, 1890) from Tasmania, and *N. hobartensis monticola* Waterhouse & Lyell, 1914 from montane areas in northern New South Wales (Braby, 2000, 2016). *Neolucia hobartensis monticola* was differentiated by several characters, namely larger size, darker underside ground colour, and darker upperside ground colour (Waterhouse & Lyell, 1914). Common & Waterhouse (1981) added that in the male the long hairs (androconia) on the upperside of the fore wing are more extensive. Material between the geographical ranges of these two subspecies (i.e. southern New South Wales, the Australian Capital Territory and Victoria) has been provisionally placed with *N. hobartensis hobartensis*, although Braby (2000, p. 820) noted that "The extent of the whitish patch on the underside of the hind wing varies considerably between populations from southern NSW, VIC and TAS." Closer examination of a large series of specimens from this region, and comparison with the types of both *N. hobartensis hobartensis* and *N. hobartensis monticola*, has revealed that this geographically isolated population(s) is indeed distinct. The purpose of this paper is to describe the population(s) from this intervening region taxonomically. We also review the occurrence of butterflies endemic to the mountains and highlands of southeastern Australia, and comment on the subspecies' restricted occurrence in montane areas and the potential risk of global climate change as a key threatening process.

The following abbreviations refer to repositories where material has been examined:

AMS	Australian Museum, Sydney
ANIC	Australian National Insect Collection, Canberra
NMV	Museum Victoria, Melbourne
QM	Queensland Museum, Brisbane
GEWC	Private collection of G. E. Wurtz, Albury

Taxonomy

Neolucia hobartensis albolineata ssp. nov.

Figs 8–11

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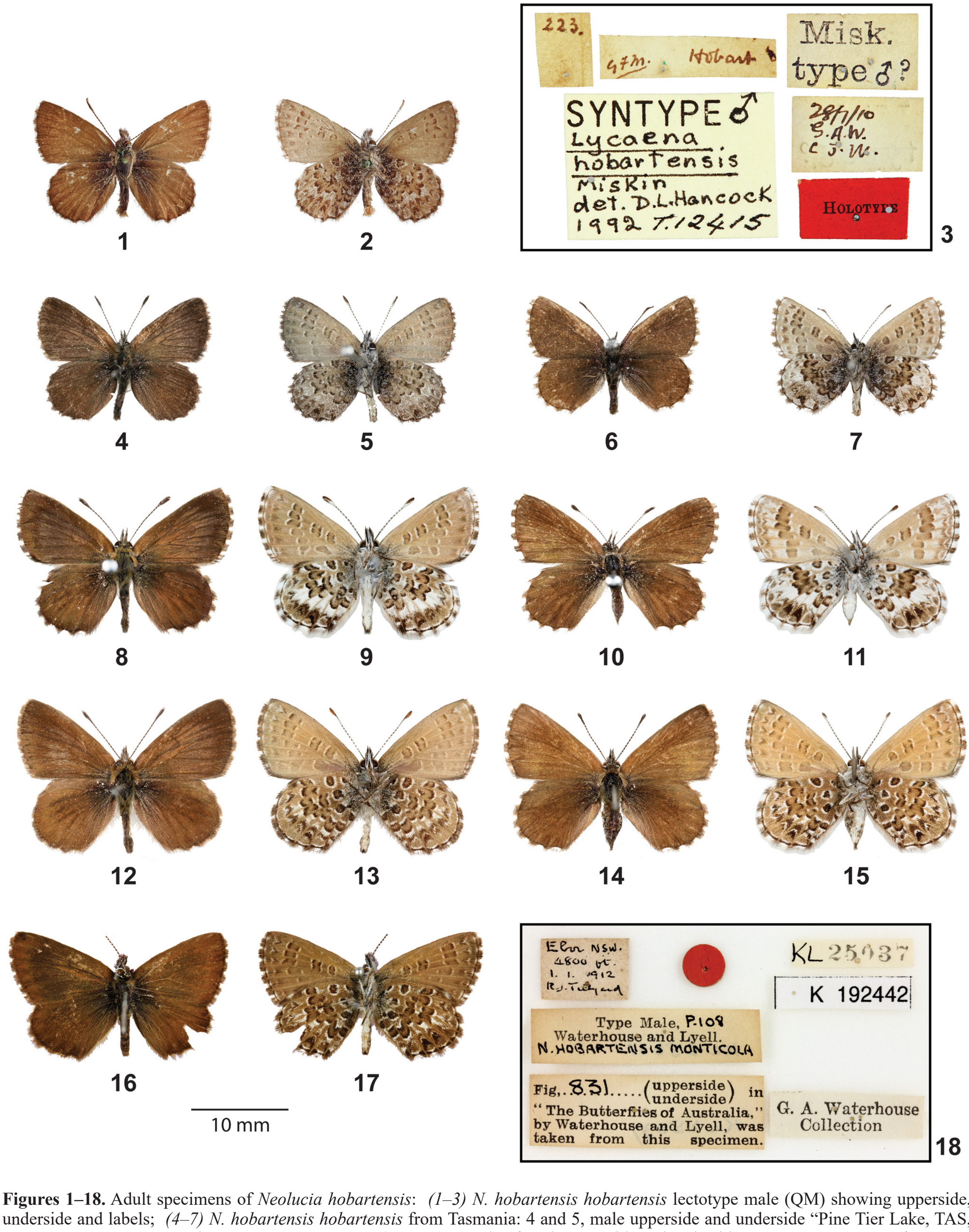
Holotype ♂, "Smokers Gap, ACT, 25 DEC. 1998, M.F. Braby" (ANIC). **Paratypes** 55♂♂, 27♀♀. **Australian Capital Territory:** ♂ "SMOKER GAP, ACT, 1244 ALT, 6 JAN 1980, NB TINDALE" (ANIC); 4♀ "SMOKER'S GAP, CORIN DAM, ACT, 26th Jan 1987, GE Wurtz" (GEWC); ♂ "Smokers Gap, ACT, 12-Jan-1992, EGGLETON" (ANIC); 3♂, 2♀ "Smokers Gap, ACT, 5 FEB. 1995, M.F. Braby" (ANIC); 5♂, 3♀ "Smokers Gap, ACT, 25 DEC. 1998, M.F. Braby" (ANIC); 9♂, 2♀ "Smokers Gap, ACT, 16 JAN. 1999, M.F. Braby" (ANIC); ♀ "Smokers Gap, ACT, emg. 8 JAN. 1999, pupated 30 DEC. 98, M.F. Braby | reared from larva on EPACRIS BREVIFLORA flowers" (ANIC); ♀ "Smokers Gap, ACT, emg. 10 JAN. 1999, pupated 31 DEC. 98, M.F. Braby | reared from larva on *Epacris breviflora* flowers" (ANIC); ♀ "Smokers Gap, ACT, emg. 10 JAN. 1999, pupated 1 JAN. 99, M.F. Braby | reared from larva on EPACRIS BREVIFLORA flowers" (ANIC); ♂ "Mt. Gingera, A.C.T., 24 Jan. 1951, M.F. Day" (ANIC); ♂ "Mt. Gingera, A.C.T. 6000 ft., 25 Jan. 1956, I.F.B. Common" (ANIC); ♀ "Mt. Gingera, A.C.T. 5500 ft., 22-1-1956, I.F.B. Common" (ANIC); 3♂ "Mt. Gingera, A.C.T. 5500 ft., 6 Feb. 1962, I.F.B. Common" (ANIC); 6♂ "Mt. Gingera, ACT. 5500 ft., 5 Feb. 1969, I.F.B. Common & A.E. May" (ANIC); ♂, 2♀ "Mt. Gingera, A.C.T. 1670 m, Emg. 25 Jan. 1971, E.D. Edwards", "6/71 Larva on flowers *Epacris petrophila*" (ANIC); ♀ same data but with date "Emg. 28 Jan. 1971" (ANIC); 4♂ "1 Ml NE of Lee's Springs, A.C.T. 4000 ft, 30 Jan. 1957, I.F.B. Common" (ANIC); ♂, 2♀ "Mt. Franklin, ACT. 4800 ft., 5 Feb. 1969, I.F.B. Common & A.E. May" (ANIC); 1♂ "[3.6 km S by road of] GIBRALTAR FALLS, TIDBINBILLA RGE, ACT, 4th Jan 1980, GE Wurtz" (GEWC); 1♂ "[3.6 km by road S of] GIBRALTAR FALLS, TIDBINBILLA RGE, ACT, 26th Jan 1987, GE Wurtz" (GEWC); 2♂ " HONEYSUCKLE CK, ACT, 29th NOV 1980, ANDREW ATKINS" (ANIC); 1♀ "Honey Suckle Crk, ACT, S 35.35.5, E 148.58, 2nd Feb 1984, GE Wurtz" (GEWC); 2♀ "Honeysuckle Ck, Namadgi NP, ACT, 1080 m, 35°35'S, 148°59'E, 15 JAN. 1995, M.F. Braby" (ANIC); 6♂, ♀ "Brindabella Ra., A.C.T., 21 Jan. 1981, J.F.R. Kerr" (ANIC); 8♂, 2♀ "2 STICKS ROAD, BRINDABELLA RANGE, W. CANBERRA, ACT, 14th Jan 1979, GE Wurtz" (GEWC); ♂ "2 km NTH of PICCADILLY CIRCUS, A.C.T., 21 JAN. 1984, K.L. DUNN, C.E. ASTON" (ANIC); ♀ "2.2 km N. Piccadilly Circus, ACT, 12 JAN. 1997, M.F. Braby" (ANIC). **New South Wales:** 6♂, ♀ "E.D. EDWARDS, 25.1.70, Boyd R, N.S.W., AUSTRALIA" (ANIC).

Other material examined An additional 638 specimens from New South Wales and Victoria currently lodged in the ANIC (263♂, 106♀), NMV (106♂, 28♀), AMS (76♂, 28♀) and GEWC (18♂, 13♀) were examined (Table 1). Locations for these specimens are as follows. **New South Wales:** South Black Range, Tallaganda NP, 9 km E of Hoskinstown (4♂, 2♀); Cumberland Range, Talbingo (2♂); Tinderry Mountains (2♂, 1♀); 2 km SE of Tantangara Dam (1♂); 10 mls E of Kiandra, NSW (2♂); 1 km W of Three Mile



Figures 1–18. Adult specimens of *Neolucia hobartensis*: *(1–3) N. hobartensis hobartensis* lectotype male (QM) showing upperside, underside and labels; *(4–7) N. hobartensis hobartensis* from Tasmania: 4 and 5, male upperside and underside "Pine Tier Lake, TAS, S42.04.14, E146.28.74, 16th Jan. 2013, G.E. Wurtz" (GEWC), 6 and 7, female upperside and underside "Mt. Barrow, T. 4000 ft., 4 Mar. 1963, I.F.B. Common & M.S. Upton" (ANIC); *(8–11) N. hobartensis albolineata* ssp. nov. from ACT and southern NSW: 8 and 9, holotype male upperside and underside "Smokers Gap, ACT, 25 DEC. 1998, M.F. Braby" (ANIC), 10 and 11, paratype female upperside and underside "E.D. EDWARDS, 25.1.70, Boyd R, N.S.W., AUSTRALIA" (ANIC); *(12–15) N. hobartensis monticola* from northern NSW: 12 and 13, male upperside and underside "Barrington Tops, NSW, 23 Jan. 1987, J.F.R. Kerr" (ANIC), 14 and 15, female upperside and underside "Barrington Tops, NSW, 23 Jan. 1987, J.F.R. Kerr" (ANIC); *(16–18) N. hobartensis monticola* lectotype male (AMS) showing upperside, underside and labels.

Table 1. Spatial data for all specimens examined. Geocoordinates (lat/long) and altitudes were either extracted directly from the specimen label data (where given), from the private database of D. F. Crosby, or inferred from the *Location* using the Gazetteer of Australia Place Name Search (http://www.ga.gov.au/placename) and Google Earth Pro. All inferred geocoordinates and altitudes are highlighted in red; the number of decimal points indicates precision.

		from label data			inferred data				
location	State	altitude	latitude	longitude	altitude (m)	latitude	longitude	♂♂	♀♀
1 mi NE of Lees Springs	ACT	4000 ft	—	—	1220	-35.3	148.8	4	—
Two Sticks Rd, 2 km N of Piccadilly Circus	ACT	—	—	—	1230	-35.3431	148.7964	9	3
Mt Franklin	ACT	4800 ft	—	—	1460	-35.4856	148.7747	1	2
[3.6 km by road S of] Gibraltar Falls, Tidbinbilla Rge	ACT	—	—	—	1190	-35.5083	148.9278	2	—
Smokers Gap	ACT	1240 m	—	—	1240	-35.5180	148.9157	20	14
Mt Gingera	ACT	5500–6000 ft	—	—	1670–1830	-35.5764	148.7797	12	3
Honeysuckle Creek, Namadgi NP	ACT	1080 m	35°35'S	148°59'E	1080	-35.583	148.983	2	3
Brindabella Range	ACT	—	—	—	—	—	—	6	1
Boyd River	NSW	—	—	—	1220	-33.9667	150.0500	6	1
South Black Range, [Tallaganda NP], 9 km E of Hoskinstown	NSW	—	—	—	1100	-35.4	149.5	4	2
Cumberland Range, Talbingo	NSW	—	—	—	1140	-35.6167	148.3667	2	—
Tinderry Mtns	NSW	4000 ft	—	—	1220	-35.7333	149.2667	2	—
2 km SE of Tantangara Dam	NSW	—	35°48'S	148°41'E	1220	-35.8	148.7	1	—
10 mi E of Kiandra	NSW	—	—	—	1340	-35.8667	148.6667	2	1
1 km W of Three Mile Dam, Kosciuszko NP	NSW	—	35°53'38"S	148°26'34"E	1500	-35.894	148.443	18	3
Ogilvies Creek	NSW	—	—	—	1400	-36.0483	148.3344	3	1
Hotel Kosciuszko, Diggers Creek	NSW	5100 ft	—	—	1550	-36.2333	148.5167	16	—
Mt Stilwell, Kosciuszko NP	NSW	1900 m	—	—	1900	-36.4167	148.3167	1	2
Alpine Way, 7 mi NE of Thredbo	NSW	3800 ft	—	—	1160	-36.4	148.4	15	1
Mt Kosciuszko [1]	NSW	4000–7000 ft	—	—	1220–2190	-36.45	148.25	80	27
Brown Mountain [12 km SE of Nimmitabel]	NSW	—	—	—	1240	-36.5983	149.3844	3	1
Mt Buffalo	VIC	4500 ft	—	—	1370	-36.7167	146.8167	3	3
Glen Wills	VIC	—	36°50'30"S	147°30'30"E	1060	-36.8417	147.5083	3	7
Tolmie [Toombullup]	VIC	—	—	—	820	-36.9167	146.2667	6	—
Mt Cope	VIC	—	—	—	1820	-36.9270	147.2811	—	2
Mt Hotham	VIC	—	—	—	1730	-36.98	147.13	18	4
Brandy Creek, Hotham Heights	VIC	—	—	—	1370	-37.0	147.2	—	1
4 km S[E] of Mt Hotham	VIC	—	37°00'30"S	147°10'30"E	1390	-37.008	147.175	—	1
Mt St Bernard	VIC	—	37°00'30"S	147°02'30"E	1070	-37.008	147.042	—	—
Cobbler Plateau	VIC	—	—	—	1580	-37.0436	146.5906	—	1
Bindaree Hut	VIC	2750 ft	—	—	840	-37.1667	146.5333	1	2
Howqua River	VIC	—	37°10'30"S	146°32'30"E	840	-37.175	146.542	2	—
2 km E of Lost Plain	VIC	1370 m	—	—	1370	-37.33	146.67	—	1

[1] Label data refers to altitudes or stations at 4000, 5000, 5400, 6000, and 7000 ft.

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Table 1. Continued.

location	State	from label data: altitude	latitude	longitude	inferred data: altitude (m)	latitude	longitude	♂♂	♀♀
Lost Plain	VIC	1480 m	37°20'S	146°40'E	1480	-37.33	146.67	1	—
Mt Reynard	VIC	—	37°23'30"S	146°45'30"E	1500	-37.392	146.758	—	—
Shaws Creek, Bennison High Plains (near Licola)	VIC	—	37°28'30"S	146°42'30"E	1300	-37.475	146.708	—	1
Shaws Creek, Tamboritha Saddle	VIC	1200–1280 m	—	—	1200–1280	-37.4767	146.7069	1	5
Lake Mountain	VIC	—	—	—	1350	-37.5	145.9	3	—
5 km N[E] of Licola	VIC	—	—	—	1000	-37.537	146.644	—	1
Mt Erica	VIC	4500 ft	37°42'30"S	146°58'30"E	1370	-37.708	146.975	31	7
Mt St Gwinear	VIC	4950 ft	—	—	1510	-37.8	146.3	2	1
Mt Baw Baw village	VIC	1470 m	37°50'28"S	146°16'03"E	1470	-37.841	146.268	1	—
Mt Baw Baw	VIC	4700–5130ft	37°50'30"S	146°16'30"E	1430–1560	-37.842	146.275	223	99
subtotals (= total 720 specimens)								519	201

Dam, Kosciuszko NP (18♂, 3♀); Ogilvies Creek (3♂, 1♀); Hotel Kosciuszko, Diggers Creek (16♂, 2♀); Mt Stilwell, Kosciuszko NP (1♂, 1♀); Alpine Way, 7 mls NE of Thredbo (15♂); Mt Kosciuszko, NSW (80♂, 27♀); Brown Mountain [near Nimmitabel] (3♂, 1♀). **Victoria:** Mt Buffalo (3♂, 3♀); Glen Wills (3♂, 8♀); Toombullup via Tolmie (6♂); Mt Cope (2♀); Mt Hotham (18♂, 4♀); Brandy Creek, Hotham Heights (1♀); 4 km S[E] of Mt Hotham (1♀); Cobbler Plateau (1♀); Bindaree Hut / Howqua River (3♂, 2♀); Lost Plain (1♂); 2 km E of Lost Plain (1♀); Shaw's Creek, Tamboritha Saddle / Bennison High Plains (16♂, 6♀); 5 km N[E] of Licola (1♀); Lake Mountain (3♂); Mt Erica (29♂, 7♀); Mt St Gwinear (2♂, 1♀); Mt Baw Baw (223♂, 99♀). It has also been collected from Mt St Bernard (1♂) and Mt Reynard (1♂), VIC (D.F. Crosby, pers. comm.).

Diagnosis. *Neolucia hobartensis albolineata* is distinguished from *N. hobartensis hobartensis* (Figs 1, 2, 4–7) by the following four character states: *(a)* specimens of both sexes are substantially larger than those of *N. hobartensis hobartensis*; *(b)* the underside ground colour of the fore wing in males is greyish-brown, with the markings usually more distinct, particularly the postmedian band which is often more contrasted (darker) against the ground colour and conspicuously edged with dark brown and then white, whereas in *N. hobartensis hobartensis* the ground colour is grey, with the markings generally more obscure or less contrasting. This character, however, is not applicable in females. *(c)* The white postmedian band or patch on the underside of the hind wing in both sexes is broader and more conspicuous, whereas in *N. hobartensis hobartensis* the white band or patch is often absent; when present it is substantially smaller in extent and less clearly defined; *(d)* the markings on the underside of the hind wing in males, particularly the subbasal and median series of spots, are generally more distinct, being darker brown against a white ground colour, although this character is variable in both *N. hobartensis albolineata* and *N. hobartensis hobartensis* and is not applicable in females. In *N. hobartensis albolineata*, the ground colour of the basal area of the hind wing may be broadly white, a feature that is absent in both *N. hobartensis hobartensis* and *N. hobartensis monticola*.

Neolucia hobartensis monticola (Figs 12–17) is similar in size to *N. hobartensis albolineata*, but it differs in having the underside ground colour of the fore wing and basal area of the hind wing brown, and the white postmedian band or patch on the underside of the hind wing absent or smaller in extent and less clearly defined. The extensive brown underside ground colour is diagnostic of *N. hobartensis monticola* and this feature no doubt contributed to Waterhouse & Lyell's (1914, p. 108) conclusion that the subspecies is "much darker both above and beneath". Dissection and examination of the male genitalia of two specimens of each subspecies revealed no significant differences between *N. hobartensis hobartensis*, *N. hobartensis albolineata* and *N. hobartensis monticola*.

Description. The species *Neolucia hobartensis* has been adequately described and illustrated previously, by Waterhouse & Lyell (1914), Common & Waterhouse (1981) and Braby (2000); hence, only a brief description is provided here for *Neolucia hobartensis albolineata.*

Male. Fore wing length 12.0 mm (holotype). Upperside dark bronzy-brown, with scale-fringe chequered dark brown

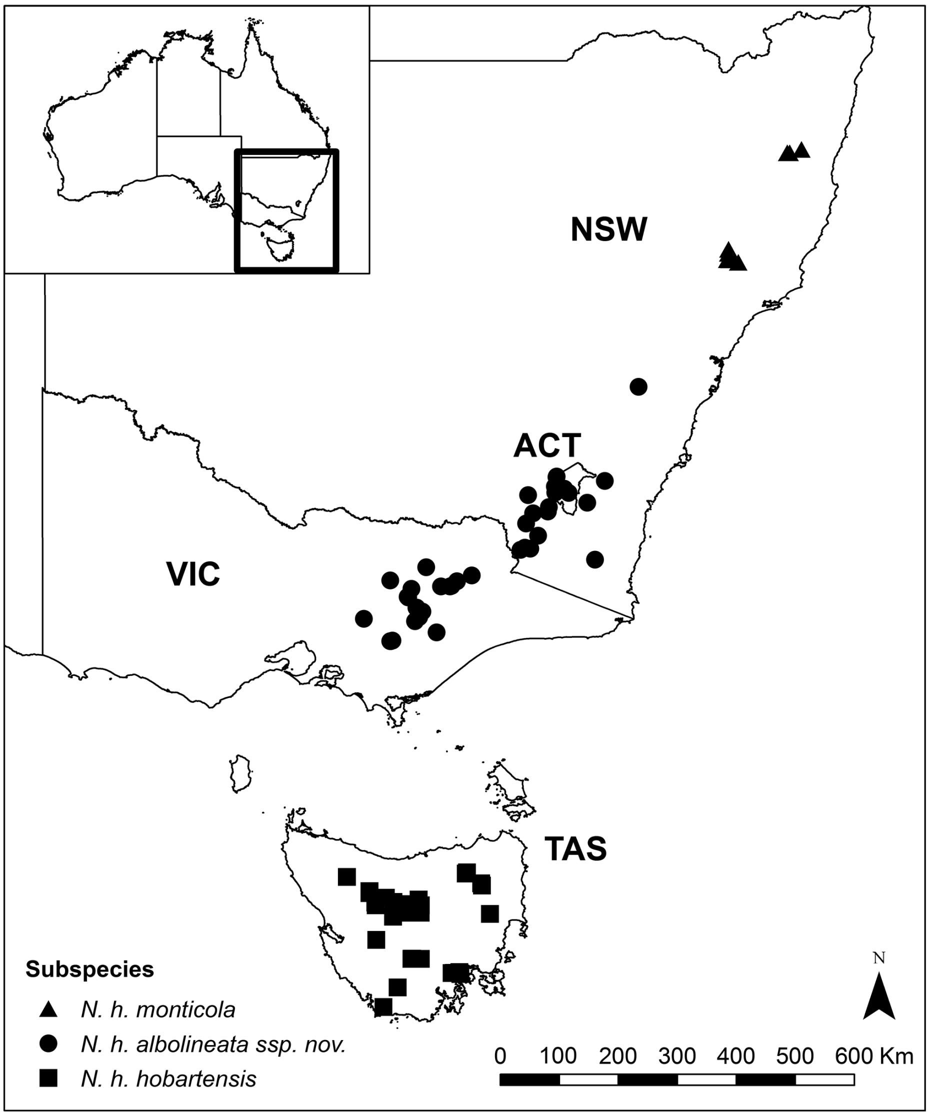

Figure 19. Map of southeastern Australia showing geographical distribution of *Neolucia hobartensis*. Records for *N. hobartensis albolineata* ssp. nov. are based on museum specimen material examined in this study, whereas those for *N. hobartensis hobartensis* and *N. hobartensis monticola* are from the Atlas of Living Australia (*biocache.ala.org.au* accessed 1 May 2018)

and white. Fore wings covered with long hairs (androconia) parallel to veins. Underside of fore wing ground colour grey-brown, with a series of slightly darker markings edged narrowly with dark brown and white, markings comprise a subbasal spot and a larger median spot in discal cell, an obscure median spot above vein 1A+2A and a conspicuous postmedian band from above vein M_1 to below vein CuA_2, followed by one or two obscure dark subterminal bands, and a narrow brown-black terminal line; hind wing with a series of dark brown subbasal and median spots or markings which often coalesce, edged narrowly with black and usually broadly surrounded with white, followed by a prominent white postmedian band or patch, usually two indistinct black inverted V-shaped subterminal marks, and a narrow black terminal line.

Female. Fore wing length 9.6–11.4 mm (paratypes). Similar to male, but upperside without androconia; underside ground colour paler with markings more distinct, and termen of wings more rounded.

Variation. Specimens from the Kosciuszko Plateau, NSW, particularly near the summit of Mt Kosciuszko (1900–2190 m), are unusual. They are smaller in size, paler brown, and the underside markings of the hind wing frequently lack the distinct contrasting pattern of spots and the conspicuous white postmedian band or patch is often absent or substantially reduced in extent. In many respects they resemble *N. hobartensis hobartensis* or *N. mathewi* (Miskin, 1890). Further investigation of this high altitude population is warranted to determine if the distinct phenotype has a genetic or environmental basis.

Remarks. *Neolucia hobartensis* was originally described by Miskin (1890) under the name *Lycaena hobartensis* Miskin, 1890 from Tasmania, with Mt Wellington near Hobart the type locality (Waterhouse, 1928). Miskin (1890, pp. 38–39) did not designate a type in the original description, which may have been based on a single specimen (but see Hancock, 1995). Waterhouse (1928) referred to a type, and Couchman (1956) referred to a holotype, though gave the sex as female, and referred to a second specimen. Hancock (1995) referred to a syntype male in the QM and gave label data. Edwards

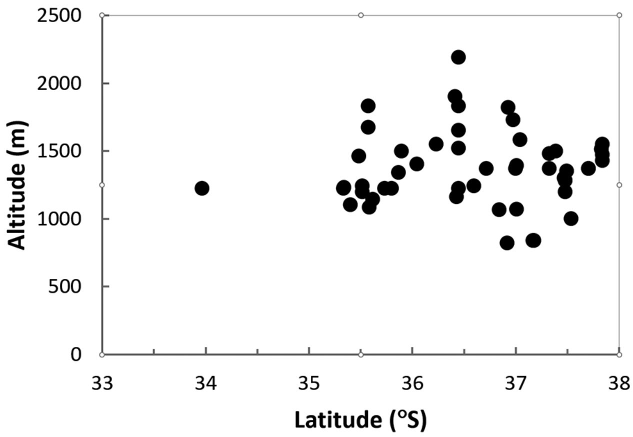

Figure 20. Scatter plot of altitude against latitude for each location of *Neolucia hobartensis albolineata* ssp. nov. based on specimen label data in the ANIC, NMV and GEWC.

et al. (2001) interpreted Waterhouse's reference to a type as a lectotype designation. The lectotype male is illustrated in Figs 1–3.

Twenty-four years after Miskin's description, Waterhouse & Lyell (1914) described the subspecies *Neolucia hobartensis monticola* Waterhouse & Lyell, 1914 based on a series of specimens from Ebor, NSW (9♂, 10♀). Waterhouse & Lyell (1914) illustrated a syntype male (figure 831), but they did not designate a type in the original description. Peters (1971) subsequently referred to a holotype in the AMS and provided a registration number (KL.25037). Edwards *et al.* (2001) interpreted Peter's incorrect reference to a holotype as a lectotype designation. We have examined the lectotype male (Figs 16–18) and the 18 paralectotypes in AMS and they agree with Waterhouse & Lyell's (1914) concept of *N. hobartensis monticola*.

It is perhaps surprising that the new geographically intermediate subspecies described herein was overlooked by G. A. Waterhouse, and has since remained unrecognized for more than 100 years since the revisionary work of Waterhouse & Lyell (1914) given the large number of specimens (721) available in public museums and the private collection of GEW from a relatively accessible and well-collected region of Australia. However, Waterhouse & Lyell's (1914) description of *N. hobartensis monticola* and examination of the G. A. Waterhouse collection in AMS revealed that in the early 1900's the diagnosis of *N. hobartensis monticola* was based chiefly on comparison of their material from Ebor with specimens from only four other locations: New South Wales (22♂, 5♀ Mt Kosciuszko), Victoria (3♂, 1♀ Mt Erica; 1♂, 1♀ Mt Hotham) and Tasmania (5♂ Mt Wellington). Thus, it is clear that of the material in AMS G. A. Waterhouse placed under *N. hobartensis hobartensis* the vast majority (71%) came from Mt Kosciuszko, most of which was collected by himself during an expedition in 27–29 January 1906 (Edwards, 2002). However, as noted above, material from the Kosciuszko Plateau is not typical of *N. hobartensis albolineata* elsewhere on the Australian mainland: although this population is variable, the specimens are generally smaller and paler and a large proportion (c. 60%) lack the diagnostic white patch on the underside of the hind wing. Thus, comparison of this anomalous high altitude population with typical *N. hobartensis hobartensis* from Mt Wellington would explain lack of recognition of the southern mainland populations as being taxonomically distinct from the Tasmanian populations at that time.

Etymology. The name *albolineata* is derived from the Latin word albus, which means white, and the Latin word lineatus, which means lined, and refers to the broad white postmedian line or band on the underside of the hind wing. The species group name is thus a compound descriptive name comprising an adjective-adjective combination with the ending of the second name in feminine form to agree with the gender of the generic name *(Neolucia)* with which it is combined, according to Article 31.2 of the International Code of Zoological Nomenclature (1999).

Distribution. *Neolucia hobartensis albolineata* occurs in southeastern Australia where it has a patchy distribution in the southeastern highlands of the mainland along and adjacent to the Great Dividing Range. It extends from the South Black Range in Tallaganda National Park east of Hoskinstown, NSW (Braby, 2000) and the Brindabella Range (1.5 km NE of Lees Spring south of Mt Coree), ACT (Kitching *et al.*, 1978), southwest to Mt Baw Baw (Quick, 1973) and Lake Mountain (Quick, 1973), VIC (Fig. 19). The record further north from the Boyd River, NSW (1220 m) (E. D. Edwards), represents a disjunct population located approximately 170 km NNE of Hoskinstown. The subspecies is restricted to montane areas, mainly above 1000 m, although a plot of available specimen data indicates no clear relationship between altitude and latitude across the geographical range of *N. hobartensis albolineata* ($r = 0.072$, $P > 0.05$) (Fig. 20). Most specimens have been collected at altitudes between 1100–1800 m. The only records above 1900 m are from the Kosciuszko Plateau, NSW, which represents the highest altitude occurrences (up to 2190 m) within the geographic range of *N. hobartensis albolineata*. The only records below 1000 m that we are aware of are the series of specimens (3♂, 2♀) from Bindaree Hut / Howqua River, VIC (840 m), collected by the late W. N. B. Quick and D. F. Crosby on 3 Dec. 1972, and another series (6♂) from Toombullup near Tolmie, VIC (820 m), collected by M. F. Braby on 17 Dec. 1983.

The published record further east of the Boyd River from Medlow Barth near Kanangra Walls in the Blue Mountains, NSW (1060 m) by Edwards (1963) is erroneous—the specimens collected are actually *N. agricola* (Westwood, 1851) (E. D. Edwards, pers. comm). Material (2♂) in the ANIC from the low altitude town of "Valencia Creek, VIC" collected by D.F. Crosby on 15 NOV. 1961 is erroneous and refers to Mt Erica (D.F. Crosby, pers. comm. 2018). A female specimen in AMS labelled "Mylor, S. Australia, 30 Nov. 1902 | 023", "G. A. Waterhouse Collection", "KL24887", and a male in AMS labelled "Woodside, S. Aust., M. W. Mules", "Nov - 22nd 1933", "G. A. Waterhouse Collection", "KL24890" are considered to be erroneous. The species is not known to occur in the Mt Lofty Ranges near Adelaide, SA.

Biology. The biology of the subspecies, including descriptions or illustrations of the immature stages, life history and developmental times, has been well documented (Quick, 1973; Common & Waterhouse, 1981; Braby, 2000; Field, 2013; Bond, 2016). The larvae specialize on the flowers and new foliage of *Epacris* spp. (Ericaceae), including *E. petrophila* Hook.f., *E. breviflora* Stapf and *E. paludosa* R.Br., growing in subalpine and alpine heathland or heathy open-woodland on acidic soils, especially along edges of swamps or along boggy creeks. The life cycle has an embryonic diapause that persists for about nine months of the year, mainly from autumn to spring.

The larval food plant of *N. hobartensis hobartensis* in Tasmania is *Epacris serpyllifolia* R.Br. (Virtue & McQuillan, 1994), whereas that of *N. hobartensis monticola* in northern New South Wales has not previously been identified. Waterhouse (1932, p. 170) reported the food plant for the latter subspecies in only general terms "… at Barrington Tops in January, this butterfly was very plentiful at the edges of the swamps, where two species of *Epacris* were growing. By beating these, I obtained a number of nearly full-grown larvae. These were all feeding on the *Epacris* with yellowish-green leaves and small white flowers." Since Waterhouse's observations, the species-level identity of the larval food plant of *N. hobartensis monticola* has remained undetermined. However, during a visit to Barrington Tops National Park, NSW the food plant was determined to be *Epacris rhombifolia* (L.R.Fraser & Vickery) Menadue—at Polblue Swamp (1450 m) adults flew in close proximity to this shrub growing along the edge of open swampland, and a female was observed on two occasions to lay eggs on the stems above the leaf axils on 27 January 2018 (M. F. Braby, unpublished data).

Discussion

The subspecies described herein fits the criteria proposed by Braby *et al.* (2012) for subspecies delineation of butterflies, namely the taxon is allopatric, phenotypically distinct (in colour pattern and morphology), and has at least one fixed diagnosable character state. We assume the taxon represents a partially isolated lineage from *N. hobartensis hobartensis* and *N. hobartensis monticola* and that the character state differences are correlated with evolutionary independence according to population genetic structure. The Bass Strait, which separates *N. hobartensis albolineata* and *N. hobartensis hobartensis*, is a well-known biogeographical barrier for many species distributed on the mainland and Tasmania; the two landmasses have been divided by an extensive water-body for the past 13,000 years (White, 1994), causing reproductive isolation for terrestrial species with limited dispersal capacity. Similarly, the Cassillis Gap, which separates *N. hobartensis albolineata* and *N. hobartensis monticola*, has been a biogeographical barrier for butterflies and other biota since the late Pleistocene, impeding gene flow between populations north of the Gap (Barrington Tops) and those south of the Gap (Blue Mountains) (Eastwood *et al.*, 2006).

Australia is a relatively flat country and is not renowned for its mountains (Australia's highest Mountain, Mt Kosciuszko, is 2,228 m), which are eroded and low in elevation (White, 1994) in comparison with other continents. The greatest topographic relief occurs in the southeast of the continent where butterfly endemism at the species and subspecies level is more pronounced, particularly among the Trapezitinae (Hesperiidae) and Coenonymphina (Nymphalidae: Satyrinae) and to a lesser extent the Theclinae-Polyommatinae assemblage (Lycaenidae) (New, 1999; Braby, 2000), highlighting the importance of the southern Great Dividing Range in the evolution of the Australian butterfly fauna. Thus, *Neolucia hobartensis albolineata* is one of a set of 22 butterfly taxa that are endemic and narrowly restricted to montane areas (>600 m, but mainly >900 m) in the tablelands and plateaus of mainland southeastern Australia (Table 2). Interestingly, the larvae of many of these montane endemic taxa (all Trapezitinae and Satyrinae) specialize on monocots, particularly Poaceae and Cyperaceae.

Further work is needed to assess the conservation status of all of these narrow-range montane endemics because their restricted high altitudinal distribution, with frequently disjunct occurrences on isolated mountain ranges and plateaus of and near the Great Dividing Range, implies that they may be susceptible to global climate change, particularly changes in temperature (Parmesan *et al.*, 1999; New, 2011). During the past century the global average surface temperature has increased by 0.6°C (Australia has warmed c. 0.8°C over this period), with much of this increase occurring during the last three decades, and further substantial rises in temperature are projected over the next 50 years (IPCC, 2001, 2007). Australian butterflies are expected to respond to these temperature changes because, being ectotherms, their metabolic and developmental rates are temperature-dependent. These responses include changes in spatial distribution (altitude or latitude), phenology (e.g., adult emergence time, flight period) and adaptation, all of which may affect levels of abundance and ecological interactions with other species, and may lead to extinction of local populations (Hughes, 2000, 2003; Beaumont & Hughes, 2002; Beaumont *et al.*, 2005). For example, a 1°C rise in mean annual temperature corresponds to a shift in isotherms of approximately 160 m in elevation or 100–130 km in latitude in the temperate zone (Hughes, 2000). Therefore, species are expected to move upwards in elevation or polewards in latitude in response to shifting climate zones. Indeed, global meta-analyses of 99 species have revealed significant upward shifts in altitudinal range, averaging 6.1 m per decade (Parmesan & Yohe, 2003).

Although the altitudinal range *N. hobartensis albolineata* is quite large (1370 m over 4° latitude), the taxon has limited capacity to expand upward and/or poleward (southward) because it already occurs near the summit of Mt Kosciuszko and at the southern limit of the Australian Alps (Mt Erica and Mt Baw Baw). Thus, the lower altitude limit of the range (820–840 m, as of 1972–1983) is more likely to be severely impacted and retract upward by global climate change, if it hasn't already. Any contraction in altitudinal range, however, will lead to substantial population isolation and fragmentation because of the discontinuous nature and comparatively low altitude of the montane country in southeastern Australia. Some populations, such as the Boyd River (1220 m), occur at their altitudinal maxima and essentially have no capacity to move upwards. Long-term monitoring of all populations of all subspecies of *N. hobartensis* is therefore required to assess how the species responds to global climate change and whether mitigating actions are needed to safeguard its future survival. Indeed, two decades ago Crosby (1998) recommended that monitoring populations of *N. hobarensis* and other alpine butterflies restricted to the Mount Buffalo

Table 2. Butterfly taxa endemic to montane areas (> c. 600 m altitude) on the mainland in southeastern Australia; compiled from data in Common & Waterhouse (1981), Braby (2000, 2016), Johnson & Wilson (2005), Sands & Sands (2017) and M. F. Braby and J. J. Armstrong (unpublished data).

species	altitude (m)	distribution	larval food plants
HESPERIIDAE: TRAPEZITINAE			
Anisynta tillyardi	900–1500	Bunya Mtns, QLD to Barrington Tops, NSW	*Poa labillardieri, P. queenslandica, P. sieberiana, P. tenera* (Poaceae)
Anisynta cynone anomala	1080–1210	New England Tableland, NSW	*Poa* sp. (Poaceae)
[a] *Anisynta monticolae*	600–1500	Blue Mountains, NSW to Black Range, VIC	*Poa tenera* (Poaceae)
Anisynta dominula dominula	600–1670	New England Tableland, NSW to Mt Donna Buang, VIC	*Poa* sp. (Poaceae)
Oreisplanus munionga munionga	1060–1600	Barrington Tops, NSW to Mt Buller, VIC	*Carex appressa, C. longibrachiata, Scirpus polystachyus* (Cyperaceae)
Hesperilla crypsargyra binna	840	Lamington Plateau, QLD	*Gahnia insignis* (Cyperaceae)
Hesperilla hopsoni	1280–1500	Near Stanthorpe, QLD to Barrington Tops, NSW	*Gahnia sieberiana, G. grandis* (Cyperaceae)
Mesodina aeluropis	820–1270	New England Tableland to Kosciuszko NP, NSW	*Patersonia* sp. aff. *sericea* (Iridaceae)
NYMPHALIDAE: SATYRINAE			
Tisiphone abeona regalis	900–1370	Near Stanthorpe, QLD to Barrington Tops, NSW	*Gahnia* spp. (Cyperaceae)
Oreixenica orichora orichora	1200–2100	Brindabella Range, ACT to Mt Tamboritha, VIC	*Poa fawcettiae, P. hiemata* (Poaceae)
Oreixenica correae	1200–1800	Brindabella Range, ACT to Mt Donna Buang, VIC	*Poa ensiformis, P. hiemata* (Poaceae)
Oreixenica kershawi ella	900–1450	Barrington Tops, NSW	Poaceae
Oreixenica latialis latialis	1200–1800	Boyd River, NSW to Mt Tamboritha, VIC	*Poa hiemata* (Poaceae)
Oreixenica latialis theddora	1230–1370	Mt Buffalo plateau, VIC	*Poa* sp. (Poaceae)
[b] *Heteronympha solandri*	840–1600	Boyd River, NSW to Grampians, VIC	*Poa labillardieri, Tetrarrhena juncea* (Poaceae)
Heteronympha banksii mariposa	600–900	Bunya Mnts to Macpherson Range and nr Stanthorpe, QLD	*Poa labillardieri, P. queenslandica, P. sieberiana, P. tenera* (Poaceae)
LYCAENIDAE			
Acrodipsas aurata	580–1060	Blue Mountains, NSW to Pine Mountain, VIC	*Crematogaster* ants
Pseudalmenus chlorinda barringtonensis	1200–1580	Mt McKenzie to Barrington Tops, NSW	*Acacia dealbata, A. melanoxylon, A. irrorata* (Fabaceae)
Candalides heathi doddi	1300–1340	New England Tableland to Barrington Tops, NSW	*Veronica perfoliata* (Plantaginaceae)
Candalides heathi alpinus	700–1820	South Black Range, NSW to Dellicknora, VIC	*Veronica derwentiana, V. perfoliata* (Plantaginaceae)
Neolucia hobartensis monticola	1200–1450	Dorrigo Plateau to Barrington Tops, NSW	*Epacris rhombifolia* (Ericaceae)
Neolucia hobartensis albolineata ssp. nov.	820–2190	Boyd River, NSW to Mt Baw Baw, VIC	*Epacris petrophila, E. breviflora, E. paludosa* (Ericaceae)

[a] The population of *Anisynta monticolae* in western Victoria in the Black Range State Park near the Grampians occurs at lower altitudes (>400 m).

[b] Disjunct populations of *Heteronympha solandri* in western and southwestern Victoria occur at lower altitudes (320–640 m, but generally >500 m), with those from the Otway Range representing an undescribed taxon (Braby, 2000).

plateau, VIC, was required to assess the impact of global climate change, especially rising temperatures. Laboratory studies investigating the degree of physiological tolerance and adaption to temperature variation are also required, including the cues inducing, maintaining and terminating egg diapause.

Related to global climate change, another potential threat facing *N. hobartensis albolineata* that needs further investigation is the increasing scale and frequency of mega fire events in southeastern Australia, such as the Canberra bushfires (18–22 January 2003) that destroyed most of the montane forests of the Australian Capital Territory and adjacent mountains in New South Wales (e.g., Kosciuszko National Park), and the Black Saturday bushfires (7 February 2009) that devastated large areas of mountainous habitat of the butterfly in Victoria. These events, and subsequent prescribed burning practices, are likely to have a detrimental effect on insects (New *et al.*, 2010). It is not known how butterflies such as *N. hobartensis albolineata* recover from such catastrophic events or what time interval is required for habitats to reach a state of ecological succession suitable for breeding post-fire. Presumably the butterfly recolonizes regrowth areas, but this clearly depends on: *(a)* the extent of refuges (spatial mosaics of unburnt patches) within the landscape, and *(b)* the dispersal capability of adults. Given the patchy and discontinuous nature of much of the species' habitat over the mountains of southeastern Australia, long-distance dispersal events between mountain peaks/plateaus are probably rare. Species of *Epacris* show a range of adaptive responses to disturbance such as high intensity fire, including resprouting from woody rootstock or basal lignotuber and regenerating from soil-stored seed after death of the parent plant with seedlings requiring at least three years to flower and set fruit (Benson & McDougall, 1995). Among the known larval food plants of *N. hobartensis albolineata*, *E. paludosa* and *E. breviflora* resprout after fire (Benson & McDougall, 1995; K. McDougall, pers. comm.), whereas *E. petrophila* is killed and recruitment may be poor following high intensity fire (K. McDougall, pers. comm.). Thus, *N. hobartensis albolineata* may be at further risk because of its ecological dependency on *Epacris* spp. growing in subalpine and alpine swampland habitats—obligate seeders such as *E. petrophila* may be diminished or possibly eliminated if the fire frequency is too high, and adult dispersal may be limited for recolonization if the spatial distance between unburnt patches is large following large-scale catastrophic fire events.

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