Australian Museum

Hill-topping Butterflies of the Hawkesbury-Nepean CMA

Hill-tops in the Estuary subcatchment

May 2008

nature culture **discover**

Natural Heritage Trust

Helping Communities Helping Australia

An Australian Government Initiative

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Executive Summary

"Loss and/or degradation of sites used for hill-topping by butterflies" has been listed as a key threatening process on Schedule 3 of the NSW *Threatened Species Conservation Act* 1995. Application of this legislation has been hindered by lack of detailed knowledge of the hill-topping butterfly fauna present in New South Wales. The Natural Heritage Trust provided funding to the Hawkesbury-Nepean Catchment Management Authority to investigate the significance of hill-topping sites in the Hawkesbury-Nepean catchment. With the involvement of the NSW Department of Environment and Climate Change, the Australian Museum was engaged to work on a pilot project aimed at educating stakeholders and providing baseline information on hill-topping butterfly communities.

Two workshops on identification and biology of butterflies were presented to stakeholders from local and state government bodies, environmental consultants, students, bush regeneration and local landcare groups.

Thirteen hill-top sites in the Estuary subcatchment region of the Hawkesbury-Nepean Catchment Management Authority were surveyed for their butterfly fauna from October 2007 to April 2008. Fifty-one species and 2,556 individual butterflies were observed, of which 40% were hill-topping species.

A set of detailed recommendations for future education and survey work have been provided based on the findings of this study.

Abbreviations used in this report.

HNCMA: Hawkesbury-Nepean Catchment Management Authority

NPWS: New South Wales Parks and Wildlife Service

DECC: New South Wales Department of Environment and Climate Change

LHP: Lepidoptera Hill-topping project

BOM: Australian Bureau of Meteorology

SG: Scott Ginn

AMS: Australian Museum, Sydney

The Variable Blotched-blue *Candalides hyacinthina hyacinthina*, a common hill-topping species observed in this study

The Bronze Flat *Netrocoryne repanda repanda*, a hill-topping skipper observed only at two sites in this study.

The Hornsby Heights site, the most diverse hill-top sampled in this study.

Introduction

Butterfly and Insect Conservation

Butterflies are often seen as a flagship group for invertebrate conservation. Insect conservation has received relatively little research and financial input compared to the conservation of vertebrates and plants. Much of this has been due to issues with charisma, perception and popularity rather than any rational assessment of significance and conservation status. Butterflies have been the one exception, and organised efforts to conserve populations of butterflies started as early as 1925 (New, 1991). They are popular insects with the general public, and with the exception of the introduced Cabbage White, *Pieris rapae*, are not perceived as "pests". However, in Australia there is not the availability of experienced observers that there is in the United Kingdom and in North America, with most knowledge of the Australian fauna derived from relatively few enthusiastic amateur entomologists. This has led to a paucity of data on the distributions and abundance of Australian butterflies, and continues to impede butterfly conservation in this country.

The national Action Plan for Australian Butterflies (Sands & New, 2002) is an important document which addresses the conservation status of all the known Australian species. In the absence of a Red List such as those made available by the IUCN in other countries (Wells et al. 1983; Henning & Henning, 1989) the Action Plan is the first port of call. It is contentious in that species for which there is little data available are treated as "data deficient" rather than placed in other categories such as "vulnerable", "threatened" or "endangered". The authors rationale for this approach is that there are extremely limited funds for the establishment of recovery plans, and it is better to focus these recovery plans on species for which there are known conservation issues. What this does highlight is the need for more research and observations on a significant proportion of the Australian butterfly fauna. This is particularly evident for taxa which are known to hill-top as adults, such as the many species of Ant-blue, *Acrodipsas* spp. (Lycaenidae). Of the nine recognised species of *Acrodipsas* the immature stages and life-histories of only two species are known with certainty, with the other seven species known from adults collected on hill-tops (Braby, 2000).

Hill-topping Behaviour

Hill-topping in butterflies usually refers to those species that have adult males that congregate on prominent or raised areas, establishing territories which they defend from other male conspecifics, and often other insect species. The reasons as to why these males select hill-tops to defend are not precisely known, but from observations it appears that butterflies and other insects utilise hill-tops as a way of finding mates. When female butterflies are observed on hill-tops they are usually unmated, and will be immediately approached by courting males, and mating ensues within a very short period of time (Baughman *et al.* 1988). Females do not remain on the hill-tops, and are more normally observed near habitats where they can find suitable larval host plants, or in the case of *Acrodipsas* and some other Lycaenidae, suitable attendant ants. These habitats may be a considerable distance away from the hill-top where mating was initiated.

Hill-tops are not necessarily conspicuous raised areas, and in level areas even large trees or slightly raised land areas can act as a focal point for butterflies (Baughman & Murphy, 1988). In sandy areas, such as in inland regions of Australia, dunes can be used as hill-tops (Douglas, 1995; Greenslade, 1994). When considering the distribution and conservation of butterflies in any habitat, it becomes important to consider whether hill-topping behaviour is playing a role in determining where the adults of certain species occur, whilst bearing in mind that the complete distribution of the species is also determined by suitable habitat for immature stages.

The large size of the Australian continent, and the relatively few active lepidopterists available for surveying butterflies means that hill-tops are sometimes the focus of collecting effort, as they often reward collectors with an increased diversity of species in the one spot. Many hill-tops have become "famous" amongst the small community of collectors, with repeated visits to capture rare taxa. This is particularly evident for Ant-blues, *Acrodipsas* spp. (Lycaenidae). Of the nine recognised species of *Acrodipsas* the immature stages and life-histories of only two species are known with certainty, with the other seven species known from adults collected on

hill-tops and a few other chance observations. In the case of *A. arcana* in New South Wales, adults are known only from Mt. Ramornie, on private land 25 km west of Grafton, with two other similarly isolated populations in central Queensland (Monteith & Yeates, 1988, Braby, 2000). As a result of many visits by collectors to this hill-top, the fauna of hill-topping adult butterflies is now well known, with forty-nine butterfly species for this one location. The fauna includes several other species for which the nearest records are in Queensland. However, this species also illustrates another potential issue with having so few available Australian butterfly observers, which is the tendency for these observers to visit locations which are already known to have populations of a species rather than to survey new areas. A further complication which is covered in more detail on page 20 in the discussion is the inability to observe and capture specimens of these small hill-topping butterflies on hill-tops with tall trees. Because of the lack of dedicated survey effort, and the difficulties in observing some hill-topping species, it cannot be said with any certainty that there are not other populations of *A. arcana* between Grafton and the areas where the species occurs in central Queensland.

New (1991) comments that barriers to short-range dispersal between breeding sites (sites where food plants, eggs, larvae and pupae occur) and the hill-top may have serious consequences in terms of reproduction, but there is no information available as to what might constitute a barrier to a butterfly. Likewise, it is difficult to establish how far butterflies will fly between breeding sites and hill-tops. In the context of hill-tops, it is also unclear as to what constitutes a degraded hill-top and one which is suitable.

Legislation for protection of butterfly communities and hill-top locations.

There have been a number of approaches to protecting Australian butterflies which are associated with hill-topping. In Victoria "Butterfly Community No. 1" was listed as a threatened community in 1991 on Schedule 2 of the Victorian *Flora and Fauna Guarantee Act 1988*. Butterfly Community No. 1 was characterised by the co-occurrence of two hill-topping species, *Acrodipsas myrmecophila* and *A. brisbanensis* (listed as *A. brisbanensis cyrilus* in documentation – this subspecies is no longer regarded as valid, Braby, 2000). To date, there is only one known location in Victoria where this occurs, which is Mt. Piper, near Broadford (Jelinek, 1991, Jelinek & White, 1996a,b). Under this legislation, the hill-tops were automatically protected as they are an essential part of the reproductive behaviour of the butterflies. The two butterfly species are also listed as individual species under the FFG Act (Jelinek & White, 1996a,b).

The Queensland approach has been to list 26 individual species of butterfly under the *Nature Conservation Amendment Act 1994*. This listing was based partially on information from an unpublished report on the conservation status of Australian butterflies (Dunn *et al.* 1994). This unfortunately resulted in unnecessary listings of species which were secure and in no danger of being extirpated, and led to some alienation of the community of butterfly collectors in Queensland (Greenslade, 1999). This has some negative consequences, including disruption of the main source of information on distribution and biology of Queensland butterflies.

The "Loss and/or degradation of sites used for hill-topping by butterflies" was listed as a key threatening process on Schedule 3 of the NSW *Threatened Species Conservation Act 1995* on the 20th April 2001 (DECC, 2008a). Although fourteen species of butterfly are mentioned in the description of the key threatening process, the listing does not directly protect any one species or community of butterflies. Nine priority actions associated with this key threatening process have been listed; these are outlined in Table 1.

Description of priority action	Priority
Threat abatement strategy: Community and land-holder liaison/ awareness and/or education	
Prepare and implement an education and community awareness publicity campaign to increase knowledge on the impacts of loss and/or degradation of butterfly hill-topping sites.	High
Threat abatement strategy: Develop and implement protocols and guidelines	
Develop habitat identification, management and enhancement guidelines.	Medium
Prepare guidelines to assist environmental impact assessment of potential butterfly hill-topping sites.	Medium
Threat abatement strategy: Establish management agreements with public authorities CMAs and land managers/owners	
Seek secure protection of key hill-topping sites.	High
Threat abatement strategy: Habitat management: Site Protection (eg Fencing/Signage)	
Erect interpretive signage at key hill-topping sites.	Low
Threat abatement strategy: Habitat Rehabilitation/Restoration and/or Regeneration	
Restore and manage degraded habitat in key hill-topping areas.	High
Threat abatement strategy: Prepare Statement of Intent	
Prepare a statement of intent by 2007.	High
Threat abatement strategy: Survey/Mapping and Habitat assessment	
Conduct targeted surveys and identify priority sites used by hill-topping butterflies.	High
Work with lepidopterist interest groups to undertake a community survey to identify butterfly hill-topping sites.	High

Table 1. A list of threat abatement strategies for the key threatening process"Loss and/or degradation of sites used for hill-topping by butterflies" (DECC, 2008a)

Project Aims

The following aims are addressed in this project.

1) Increase community awareness of butterflies and the role of hill-tops in their reproduction

2) Provide information to community groups for assessment of butterfly populations

3) Systematically survey hill-tops in part of the area of the HNCMA

4) Assess the relative status of hill-tops in the survey in respect to their butterfly fauna

5) Determine if habitat loss and/or degradation has affected the butterfly fauna of surveyed hill-tops

6) Identify priority hill-topping sites

7) Outline methodologies for surveying hill-tops for future studies

Methodology

Site Descriptions

A total of 17 locations were visited during the course of the study. The original brief allowed for choice of sites within the HNCMA. On the basis of the limited available budget and other practical logistic considerations it was decided to work in an area to the north of Hornsby which falls within the Estuary area of the HNCMA. Figure 1 is a map of the sites with an orthographic overlay. Table 2 lists the sites, site codes, locations, altitude, general habitat, time since fire and percentage canopy cover at each location. Vegetation in the area is generally Hawkesbury Sandstone vegetation, with varying degrees of disturbance, timing of fire events and weed infestation. Suburban development encroaches on much of the surveyed area, and this has promoted many forms of disturbance, such as the presence of invasive weeds, altered fire regimes, tracks and feral animals. Botanical site assessments were carried out by L. Holme (DECC) with the exception of the Cherrybrook site which was done by SG; these results are not presented in the report, but are available on request. Fire histories of sites were obtained from records held by DECC (M. Ghosn).

The geography of the surveyed area meant that the isolated peaks characteristic of "classic" hill-topping localities are not present. In the absence of these peaks the physical characteristics used to select sites as "hill-tops" were that they were the highest points of ridgelines.

Survey Methods

Sites were visited on repeated occasions, with a total of 69 site visits to the 17 sites. Two sites (Muogomarra and Mt Colah) were only visited once, with three locations within Muogomarra visited on the same day, and were omitted from further analyses of data in the results. The remaining thirteen sites were visited five times each over the duration of the study for a total of 65 visits.

As many butterfly species are active for only part of the day an effort was made to vary the time each site was visited so as to maximise opportunities for observing the full complement of butterflies at each site. Field work was conducted when weather conditions were conducive for butterfly activity. Butterflies are generally inactive during cool cloudy weather, or in extremely hot weather. Windy conditions will also negatively affect butterfly activity, and can hinder accurate observations. Occupational health and safety issues with sending observers into forested areas during conditions of high wind speeds and temperatures were also taken into account. Temperatures in the field during observation periods ranged between 22 to 34.2 C°, with the average observation temperature 27.3 ± 0.3 C°, wind speeds ranged between 0 to 3.9 m/s, with an average of 1.2 ± 0.1 m/s, and percentage relative humidity ranged between 18 to 80 % RH, with an average of 54.4 ± 1.7 % RH. The methodology in this study was to observe as many butterfly species as possible during each observation period within the limited area of each hill-top/ridge. The time taken for observations at each site averaged 54 ± 3 minutes, with the longest observation 3 hours and 15 minutes, and the shortest 10 minutes. In general, this allowed for four sites to be assessed each day in the field with one field team and associated vehicle.

The area available for observations on each ridge/hill-top varied considerably between sites. Our approach was to treat the entire area which may act as a hill-top as the sample area, rather than to use a repeated area for sampling. The reasons for this were that it was not always clear what area on a ridge was being used for hill-topping behaviour, and by establishing a fixed sample area located in one part of a ridge for observation we might miss many of the critical species at that site. We wanted to maximise the opportunities to observe all of the potential hill-topping species at each locality. During the sampling period, the observer would traverse the available space on the ridge/hill-top, and identify and count the number of individuals of each species present there. This does create the possibility of counting some individuals more than once, but the analysis used (see below) removes much of the bias caused by variations in abundance of species.

Geographic data (Location, Latitude/Longitude, Elevation, Aspect) was recorded for each site on first visitation.

Site Code	Site	Location	GPS co-ordinates (System Aus Geocl.'84)		Elevation (m)	Habitat	% Canopy Cover	Time since fire (years)
			Long	Lat				
LHP002	Wahroonga	Cook Trig, trail off Grosvenor St	33°41'58.02"S	151° 7'35.4"E	204	low-medium disturbed eucalypt woodland; hill-top	45	4
LHP003	Hornsby Heights	Berowra Valley Bushland park, end of Somerville Rd	33°38'27.3"S	151°06'42.3"E	189	low disturbance eucalypt woodland; ridge with peaks	40	3
LHP004	Galston	Elecricity tower access on Crosslands Rd	33°38'13.2"S	151° 5'54.6"E	200	low disturbance eucalypt woodland; hill-top	60	11
LHP005	Dural	Berowra Valley Bushland park, Pogson Trig, end of Quarry Rd	33°41'31.9"S	151°04'17.7"E	209	eucalypt/ banksia woodland ridge with hill-top peak	40	2
LHP006	Glenorie	End of Ben Bullen Rd	33°35'15.7"S	151°01'55.3"E	176	eucalypt woodland, sandstone rock oucrop; hill-top	40	5
LHP008	Yoothamurra	Forest Glen, western side of Old Northern Rd, 9.0 km N of Cairnes Rd	33°31'48.3"S	151° 0'45.5"E	210	eucalypt woodland; ridge	50	6
LHP010	Canoelands	Electricity tower track on northern side of Canoelands Rd, 5.8 km from Old Northern Rd	33°29'55.8"S	151°04'05.3"E	279	eucalypt woodland; hill-top	20	5
LHP012	Beckett's Forest	Western side of Old Northern Rd, 4 km N of Canoelands Rd turnoff	33°28'39.8"S	151°00'30.8"E	224	eucalypt woodland; ridge hill-top	20	6
LHP013	Wiseman's Ferry	Hill above Hawkin's Lookout eastern side of Old Northern Rd	33°24'23.2"S	150°58'57.9"E	199	eucalypt woodland; hill-top	40	6
LHP014	Metheringham's Hill	Western side of Old Northern Rd, 1.9 km S of Hawkin's Lookout	33°25'9.90"S	150°58'17.50"E	190	eucalypt woodland; hill-top	20	6
LHP015	Cliftonville	Powerline easement track west off Cliftonville Rd	33°27'48.4"S	150°56'13.8"E	177	eastside - eucalypt woodland, west side - heathland scrub	10	6
LHP016	Sth Maroota	Sth Maroota Reserve, Electricity tower, Charcoal Rd	33°31'33.0"S	150°56'16.4"E	97	relict eucalypt/ banksia scrub	10	2
LHP018	Muogomarra*	Muogomarra Nature Reserve Site 1, restricted access road NW hill-top, track off to right	33°33'35.6"S	151°11'13.4"E	217	eucalypt woodland; hill-top	no data	6
LHP019	Muogomarra*	Muogomarra Nature Reserve Site 2, Kimmerikong Ridge, restricted access road	33°32'57.9"S	151°10'44.5"E	210	eucalypt/ banksia woodland ridge with hill-top peak	no data	6
LHP020	Muogomarra*	Muogomarra Nature Reserve Site 3, secondary track below rock ledge ridge	33°33'19.8"S	151°11'15.6"E	187	eucalypt woodland; secondary track below rock ledge ridge	no data	6
LHP021	Cherrybrook	Electricity tower access track, end of Trevor's Lane	33°42'36.5"S	151°03'34.2"E	193	eucalypt woodland; ridge with hill-top peak	40	11
LHP022	Mt Colah*	Kalkari Visitors Centre, Kuringai Chase National Park, Birrawanna Track	33°40'0.21"S	151°08'55.4"E	190	disturbed eucalypt woodland	no data	1

Table 2 Site locations and codes. "*" indicates sites which were only visited once. These were not included in the main analyses.

The following data was collected on each site visit:

- Climatic data (General description, Air temperature, Average wind speed, % Relative Humidity)
- Time of visit
- Observers/Collectors
- Species data (Species, Sex, Estimated abundance, Condition, Behaviour, Flight Pattern)
- General notes on habitat, food plants, attendant ants, and any immature stages observed.

An example of site data sheet is provided in Appendix I.

Climatic data was gathered using a Kestrel 3000 Pocket Weather Meter (http://www.kestrelweather.com.au/), and was augmented by monthly data downloads from the Australian Bureau of Meteorology (http://www.bom.gov.au) for weather stations located at Terrey Hills and Parramatta. Identifications were made using Braby (2000, 2004), and by comparison with identified specimens in the AMS entomology collection. Voucher specimens were taken when necessary, particularly in groups which are difficult to identify, such as the Hesperiidae and Lycaenidae. These specimens are stored in the entomology collection at the AMS, and can be located by searching the Museum database using the "LHP" prefixed collection event codes specified in the site descriptions (Table 2).

Analysis of diversity

Errors associated with means are either the standard error of the mean, or in the case of averaged percentages, the 95% confidence interval.

To enable comparison of alpha level diversity between sites Hill's Indices (H0, H1, H2) were calculated for each site (Hill, 1973). These indices show the total species richness per site (H0), relative richness per site weighted by presence/absence of rarely collected species (H1), and the impact of abundant species (H2). H1 and H2 values can be compared to other studies. Species accumulation curves were generated using BioDiversity Pro (McAleece *et al.* 1997), and estimates of the total number of species present in the overall study area generated.

Community Workshops

Two community workshops were held (10 November 2007, 5 April 2008) with morning oral presentations to community members at the Kalkari Visitors Centre, Ku-ring-gai National Park. Attendees were taken to a field location in the afternoon for each workshop (Dural in November 2007, Hornsby Heights in April 2008). D. Britton presented the oral section, and S. Ginn presented the field section. Informal feedback from the workshops was gathered, but no formal assessment of the presentation and content of the workshops was made.

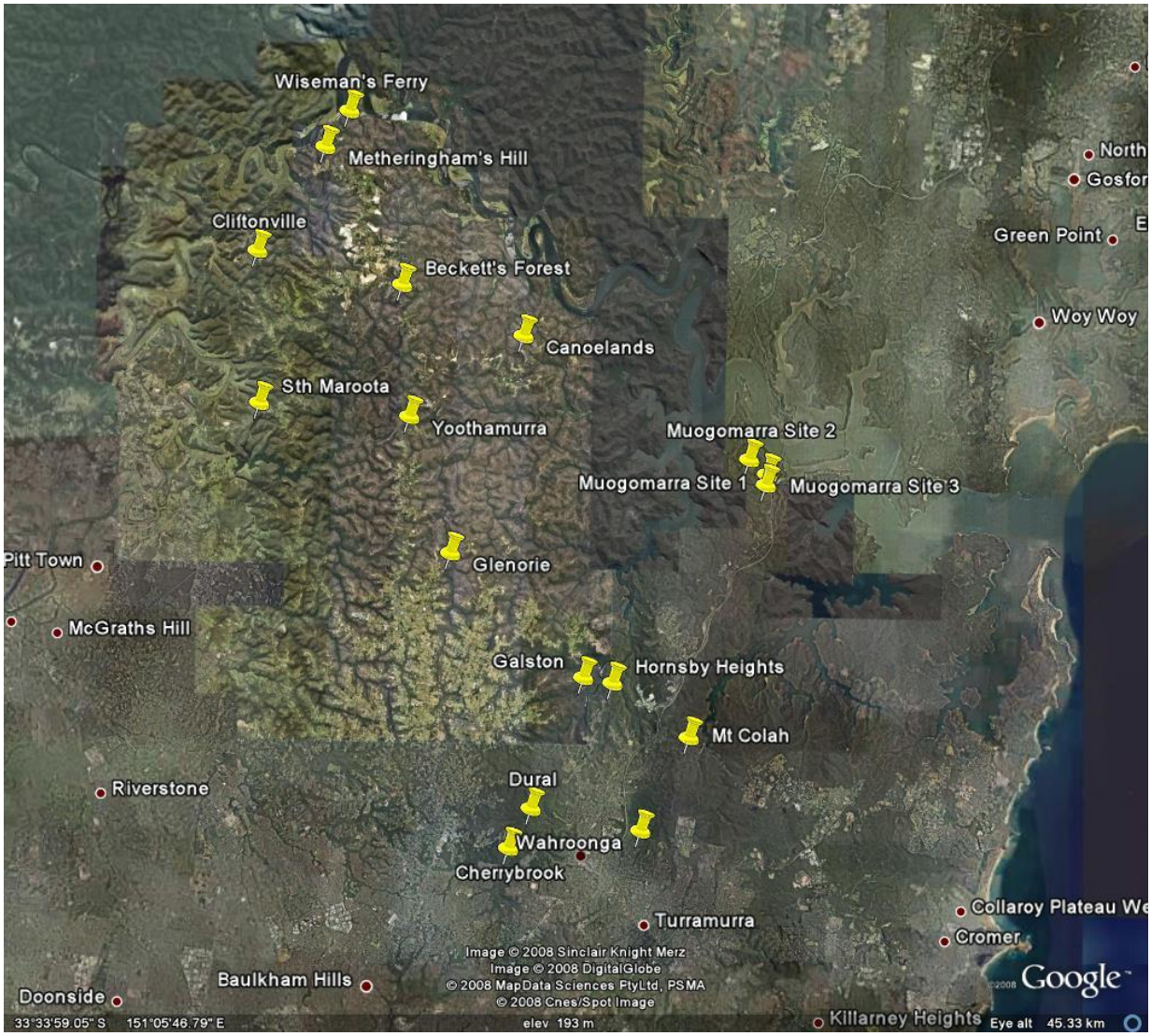

Figure 1. Locations of the 17 surveyed sites (map from Google Earth, May 2008)

Results

Diversity

Table 3 lists presence/absence, abundance, and number of hill-topping species for each site. A total of 51 species of butterfly and skipper were observed at the thirteen study sites, with an average of 17 species per site. The most species rich site was the ridge at Hornsby Heights, with 29 species recorded. Sites which were only visited once and not included in the main analyses here represented the least species rich sites in the study (Mt. Colah, with 4 species, Muogomarra with 11), but some sites which were visited multiple times throughout the study were also lacking in species richness, such as Cherrybrook (14 species), Yoothamurra (13 species) and Wahroonga (14 species). Three species were found at all surveyed sites, *Heteronympha merope*, *Candalides hyacinthina* and *Zizina labradus*, whilst eleven species were only found at one site (see Table 3 for details). Appendix II lists individual species accounts.

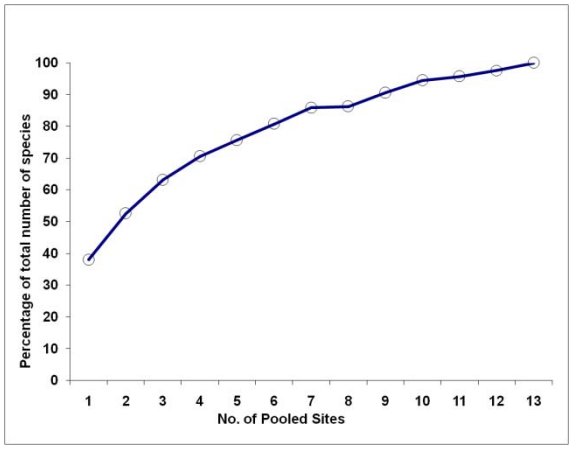

Figure 2 Percentage accumulation of butterfly species over thirteen sites

A species accumulation curve plotted using the data indicated that sampling effort in the study indicated that eleven sites accounted for over 95% of the total number of species in the study (Figure 2). This curve was extrapolated using the Chao 2 estimation method in BioDiversity Pro (McAleece *et al.* 1997) (Figure 3). This estimation uses repeated (100 runs) random subsampling of the existing data, and will deliver somewhat different answers each time the analysis is performed. The projected diversity of the butterfly community at the sampled ridgetops if more sampling was done was between 57 and 79 species, with a mean of 65 species (n=15).

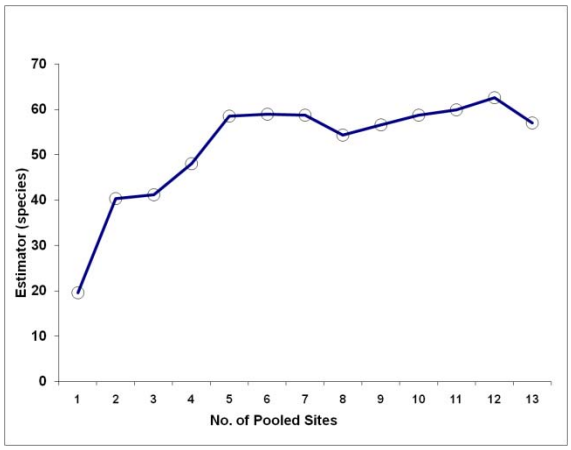

Figure 3 Example of an output from the Chao 2 analysis.

Hill's diversity indices (H0, H1, H2) were calculated for the thirteen sites. The pattern of diversity for the remaining sites was different when rare taxa were taken into account with the H1 index, with the lowest diversity sites being Canoelands, Sth Maroota and Metheringham's Hill, instead of Cherrybrook and Yoothamurra (Figure 4). This reflects the influence of rarely observed taxa such as *Heteronympha paradelpha*, which was only found at Yoothamurra and *Graphium sarpedon*, which was only observed at Hornsby Heights and Cherrybrook. The taxa found at Canoelands, Sth Maroota and Metheringham's Hill are those that occurred at the majority of other sites, hence the lower values of H1. The more abundant species observed in this study did not have an effect on the Hill's numbers (H2), as they were present at nearly all of the surveyed sites and all of the calculated H2 values = 0.

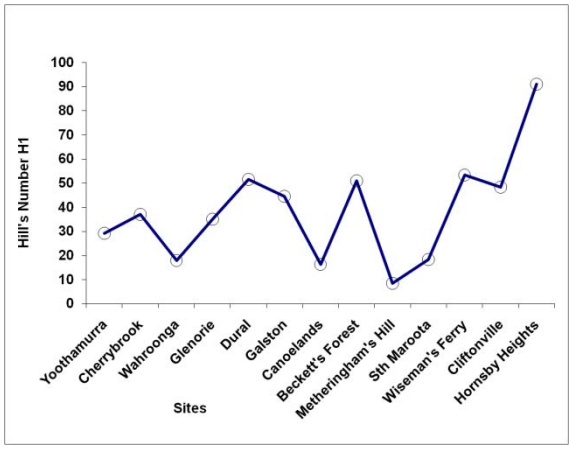

Figure 2 Hill's diversity index H1 for each site

* = species not resident † = species is known to hill-top	Wahroonga	Hornsby Heights	Galston	Dural	Glenorie	Yoothamurra	Canoelands	Beckett's Forest	Metheringham's Hill	Wiseman's Ferry	Sth Maroota	Cliftonville	Cherrybrook	Total individuals observed	Frequency of observation	No. of sites present
Acraea andromacha†*											2	2		**4**	**3**	**2**
Appias paulina ega†*										1				**1**	**1**	**1**
Argynnina cyrila†				1										**1**	**1**	**1**
*Belenois java teutonia**		1		2	2			5	6					**16**	**6**	**5**
Candalides acasta†		1	10		6			21	3			8		**49**	**12**	**6**
Candalides cyprotus†			12	5										**17**	**3**	**2**
Candalides hyacinthina†	15	11	53	8	38	11	2	38	4	18	1	4	13	**3**	**38**	**13**
Candalides xanthospilos		1			3						1			**5**	**4**	**3**
Danus plexippus				1					1		1			**3**	**3**	**3**
Delias nigrina†	6	8	9	16	8	2	4	3	3		4	5	3	**71**	**30**	**12**
*Eurema hecabe**		1												**1**	**1**	**1**
*Eurema smilax**				1										**1**	**1**	**1**
Geitoneura acantha		2			3		1		6	1	1	57		**71**	**13**	**7**
Graphium macleayanus†			1	1										**2**	**2**	**2**
Graphium sarpedon †	1	1											2	**4**	**4**	**3**
Heteronympha banksii								1						**1**	**1**	**1**
Heteronympha merope †	6	8	4	22	3	14	3	13	13	10	41	18	12	**167**	**38**	**13**
Heteronympha mirifica								1						**1**	**1**	**1**
Heteronoympha paradelpha						1								**1**	**1**	**1**
Hypocysta adiante		4					36	4	450	33	10	280		**817**	**24**	**7**
Hypocysta metirius	13	1		2	2			2						**20**	**9**	**5**
Hypocysta pseudirius		15	9	7	13	1	8	26	55	13	2	50	8	**207**	**34**	**12**
Jalmenus evagoras			3							31				**34**	**5**	**2**
Junonia villida calybe		2					1		2	1	3	2	1	**12**	**9**	**7**
Mesodina halyzia		2	3	4	3	1	2		1	9	2	1	3	**31**	**20**	**11**
Nacaduba biocellata	1													**1**	**1**	**1**
Neolucia agricola		25	38	20	10					20		10		**123**	**8**	**6**
Netrocoryne repanda†			1					2						**3**	**2**	**2**
Ocybadistes walkeri	10	10				1	1	2	4	1	2	8		**39**	**20**	**9**
Papilio aegeus aegeus		4	2	3	2		2	1	1	2	1	1	4	**23**	**21**	**11**
Papilio anactus†							3	1	1	1		1		**7**	**6**	**5**
Paralucia aurifer		1												**1**	**1**	**1**
Pieris rapae rapae		1			1								1	**3**	**3**	**3**
Polyura sempronius†							1							**1**	**1**	**1**
Prosotas felderi	102						1			1		2		**106**	**5**	**4**
Sahulana scintillata†					1		1							**2**	**2**	**2**
Suniana lascivia	1													**1**	**1**	**1**
Tisiphone abeona†	7	3	15	7	5	1	1	16	5				6	**66**	**21**	**10**
Toxidia doubledayi		1									2			**3**	**3**	**2**
Toxidia parvulus										1	1			**2**	**2**	**2**
Toxidia peron†		8	2	1		4	5	7	17	13	5	3		**65**	**21**	**10**
Trapezites eliena†		2								6	3			**11**	**8**	**3**
Trapezites iacchoides†		2	3											**5**	**3**	**2**
Trapezites petalia†										4	1			**5**	**3**	**2**
Trapezites phigalia†						1		1			1			**3**	**3**	**3**
Trapezites praxedes†			1			3	1	1	5	1	2	2	1	**17**	**10**	**9**
Trapezites symmomus	4	6	3	1	2		1	4	3	1	1		3	**29**	**17**	**11**
Vanessa itea†	4	4	7	2						2				**19**	**13**	**5**
Vanessa kershawi	12	13	28	23	7	6	10	12	2	6	4	2		**125**	**20**	**12**
Ypthima arctous		2					1		39		8	84		**134**	**13**	**5**
Zizina labradus labradus	6	1	2	5	50	2	100	13	6	1	7	26	3	**222**	**22**	**13**
Total species at site	**14**	**29**	**20**	**20**	**18**	**13**	**21**	**21**	**21**	**23**	**24**	**20**	**13**			
Total hill-topping species	**6**	**9**	**12**	**9**	**6**	**5**	**8**	**9**	**7**	**8**	**8**	**7**	**5**	**Total observed**		**2556**

Table 3 Presence/absence and abundance of butterfly species at the main survey sites. Shaded cells with numbers indicate presence and total abundance of a species at each site for five site visits.

Abundance

A total of 2,556 butterflies and skippers were observed at the thirteen main sites. The most frequently observed species during the study were *Heteronympha merope*, *Candalides hyacinthina*, *Hypocysta pseudirius*, and *Delias nigrina*, observed on 38, 38, 34 and 30 site visits respectively from a total of 65 site visitations. When *Hypocysta adiante* was present at a site it was the most abundant species, with an average of 34 specimens seen on each site visit, and it was also the most abundant species seen in the study with a total of 817 individuals noted (see comments on reliability of abundance data on page 20 in the discussion). Other abundant species included *Hypocysta pseudirius* (207 individuals) and *Zizina labradus labradus* (222). Eleven species were represented by sightings of a single individual, including *Appias paulina ega, Argynnina cyrila, Eurema hecabe hecabe, E. smilax, Heteronympha banksii banksii, H. mirifica, H. paradelpha, Nacaduba biocellata biocellata, Paralucia aurifer, Polyura sempronius*, and *Suniana lascivia lascivia*. Summaries of abundance data per species per site are provided in Table 3.

Hill-topping behaviour

An average of 39.5 ± 3.6% of species observed at each site were hill-topping species. Of the species observed in the study 43% were hill-topping species (see comments on page 18 in the discussion on the definition of hill-topping behaviour). At the most species rich site (Hornsby Heights) one third of the species exhibited hill-topping behaviour, and none of the regularly visited sites had a composition of less than 30% hill-topping species. The highest percentage of hill-topping species was observed at Galston (55%).

Vagrant versus resident species

Forty-seven of the 51 species observed in this study breed in the Sydney region. Four species are vagrant, and of these only *Acraea andromacha, Appias paulina ega* display hill-topping behaviour. These species are distinctive, and are unlikely to affect assessment of hill-topping sites.

Seasonal changes in species composition

Table 4 lists flight periods per species across all sites. Several species observed in the study had limited flight periods. Species which were only present in spring include *Argynnina cyrila, Trapezites iacchoides, T. phigalia, Netrocoryne repanda repanda, Belenois java teutonia* (a vagrant species whose migration occurs in October/November), *Candalides cyprotus cyptrotus*, and *Neolucia agricola*. Similarly, some species were only present in late summer/autumn. These were *Dispar compacta, Trapezites petalia, T. praxedes, T. symmomus symmomus, Acrea andromacha andromacha* (a seasonal vagrant), *Heteronympha banksii banksii, H. paradelpha, Prosotas felderi*, and *Sahulana scintillata*. These seasonal variations in adult flight period are most notable in single brooded species (e.g. species which only have one generation per year). Multiple brooded species may also display seasonal variation, particularly in species such as *Delias nigrina* which may have two or more broods per year which produce adults that fly in spring, and in autumn.

The greatest overall species richness on hill-tops in the study was observed in February (33 species observed), followed by October (26 species observed). Observations in both of these months also recorded the largest number of hill-topping species, with 13 observed in October, and 15 observed in February. January and March were also species rich, with 28 species observed in each of these months.

Influence of weather on butterfly behaviour in 2007/08

The overall summer of 2007/08 was characterised by relatively low average temperatures and increased rainfall in coastal areas (BOM , 2008). Data collected during field work may not reflect this since field trips were generally made in reference to forecast and prevailing weather conditions, and field workers would not go out on cold or wet days. Due to this, it is not possible to directly compare butterfly abundance and diversity with climatic conditions. However, greater than average rainfall and cooler than average temperatures experienced over the 2007/08 summer (BOM, 2008) promoted grass growth, and this was reflected in the large numbers of small grass-feeding satyrine butterflies such as *Hypocysta adiante* and *H. pseudirius*. The cooler temperatures overall might be expected to influence butterfly activity, and the developmental stages of butterflies, but this was not evident in the data on abundance and diversity collected in this study.

* = species not resident	September	October	November	December	January	February	March	April
*Acraea andromacha**								
*Appias paulina ega**								
Argynnina cyrila								
*Belenois java teutonia**								
Candalides acasta								
Candalides cyprotus								
Candalides hyacinthina								
Candalides xanthospilos								
Danus plexippus								
Delias nigrina								
*Eurema hecabe**								
*Eurema smilax**								
Geitoneura acantha								
Graphium macleayanus								
Graphium sarpedon								
Heteronympha banksii								
Heteronympha merope								
Heteronympha mirifica								
Heteronoympha paradelpha								
Hypocysta adiante								
Hypocysta metirius								
Hypocysta pseudirius								
Jalmenus evagoras								
Junonia villida calybe								
Mesodina halyzia								
Nacaduba biocellata								
Neolucia agricola								
Netrocoryne repanda								
Ocybadistes walkeri								
Papilio aegeus aegeus								
Papilio anactus								
Paralucia aurifer								
Pieris rapae rapae								
Polyura sempronius								
Prosotas felderi								
Sahulana scintillata								
Suniana lascivia								
Tisiphone abeona								
Toxidia doubledayi								
Toxidia parvulus								
Toxidia peron								
Trapezites eliena								
Trapezites iacchoides								
Trapezites petalia								
Trapezites phigalia								
Trapezites praxedes								
Trapezites symmomus								
Vanessa itea								
Vanessa kershawi								
Ypthima arctous								
Zizina labradus labradus								
Total	**13**	**26**	**22**	**19**	**28**	**33**	**28**	**17**
Total (hill-topping species)	**7**	**13**	**11**	**8**	**12**	**15**	**12**	**10**

Table 4 Monthly presence of butterfly species at the main survey sites. Shaded species are known to hill-top.

Effect of time since fire

Nearly all of the surveyed sites had been burnt within the last six years, with the average time since fire being 5.6 ± 0.7 years. The number of species and abundance was compared against time since fire (Figures 5 & 6). A linear regression against this data indicated that there was a slight negative trend, with fewer species and fewer individuals observed at sites which had not been recently burnt, but this relationship was not significant (R^2 = 0.11, R^2 = 0.07 respectively). Parts of the most diverse site (Hornsby Heights) had been burnt three years prior to the study, but the effects of this recent burn was not immediately apparent at the areas surveyed in this study, and consultation with DECC staff indicated that the burn was cool and patchy in this area (pers. comm. M. Ghosn).

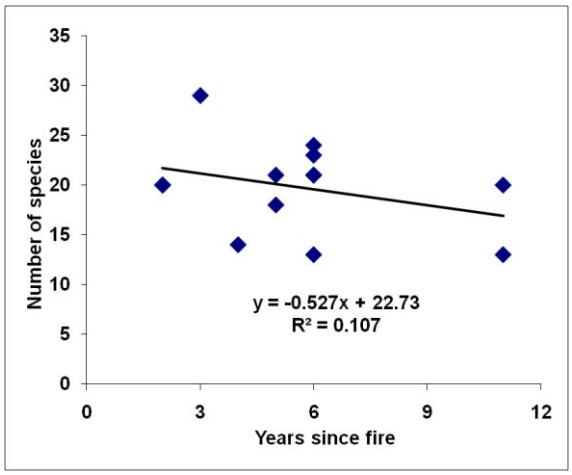

Figure 5 The relationship between number of butterfly species and years since fire.

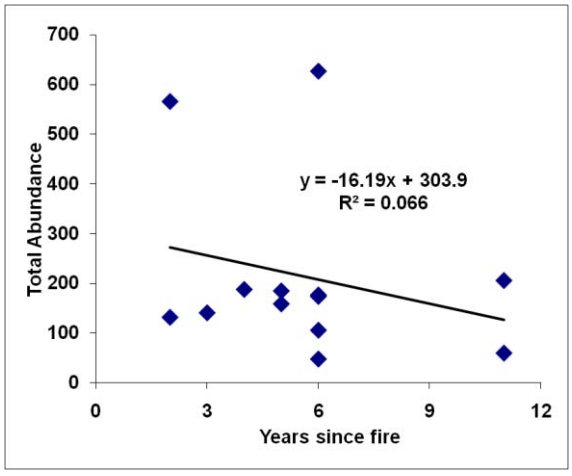

Figure 6 The relationship between butterfly abundance and years since fire.

Site habitat variables and their effect on butterfly diversity

Within a hill-topping site in this survey there could be considerable variation in percentage canopy cover. For example, at Cliftonville it varied between 5 – 30% cover of trees greater than 4m high. Because of this large within site variability direct correlation of percentage canopy cover with butterfly species diversity is somewhat difficult. Figure 7 is a plot of species richness per site against percentage canopy cover. There is a slight negative trend in species richness, with more closed sites having fewer species observed, but this is not significant (R^2 = 0.12). When the average total abundance of butterflies observed at sites was compared to percentage canopy cover a slightly stronger negative relationship was observed (R^2 = 0.24) (Figure 8).

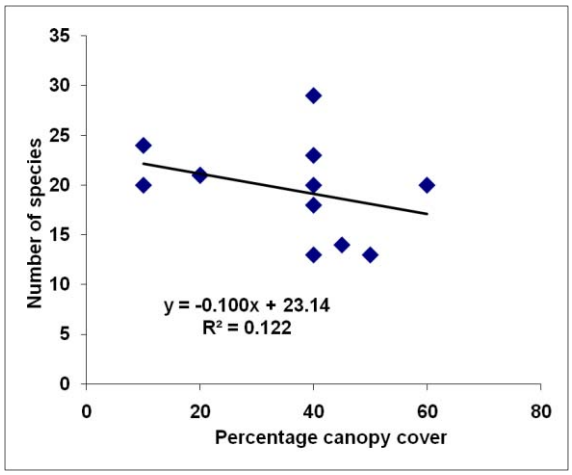

Figure 7 The relationship between number of butterfly species and percentage canopy cover.

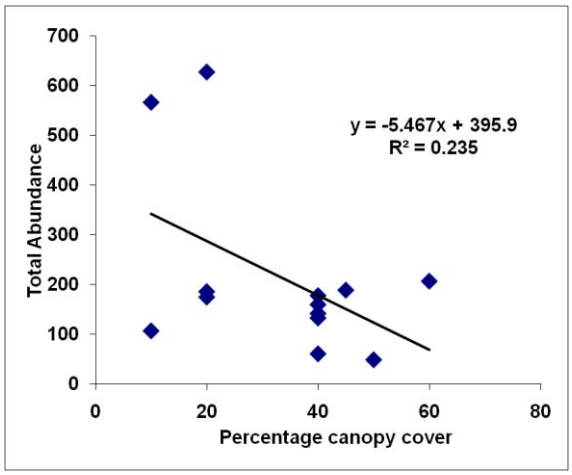

Figure 8 The relationship between butterfly abundance and percentage canopy cover.

It was observed at sites where there was considerable vegetation cover that most of the activity occurred in the presence of native vegetation with >20% canopy cover. The general open nature of much of the native vegetation at the surveyed sites meant that there were no examples of dense canopy cover, so it was not possible to definitely say whether there was a requirement for more open habitat for hill-topping butterflies.

The basic composition of the vegetation communities at each hill-top was similar for many of the sites (summarized in Table 2). Some sites had obvious habitat degradation, with the presence of exotic weeds, open areas created by human activities such as bike riding, maintenance of power line easements and quarrying, as well as evidence of recent and severe fire events. These included Sth Maroota, Wahroonga and Canoelands. With the possible exception of Wahroonga, this did not seem to have an effect on the hill-topping butterfly communities present at these sites. Wahroonga had very little understorey present in areas 100 m away from the summit, and the vegetation surrounding the summit was heavily disturbed, with several species of introduced weed present.

Community Workshops

Community workshops were over-subscribed on both occasions, and attendees were generally very satisfied with the content and presentation of the subject material. Workshop 1 (November) attracted 31 attendees, with an additional 10 on a waiting list, and Workshop 2 (April) had 27 attendees. Attendees came from a variety of backgrounds, including bush regeneration groups, volunteers associated with the National Parks association, native plant nurseries, local councils, university students, private environmental consultants, general community members, and DECC employees (including NPWS personnel). The time available meant that only the very basic aspects of butterfly identification and field method could be presented. This included a brief discussion of the significance of invertebrates to the environment and to humans, the role of butterflies as flagship invertebrates, the complexity of butterfly life histories, and the challenges that presents for field workers. This was followed by a display of some local butterfly food plants, and some immature stages of some species, including *Tisiphone abeona abeona*, *Delias nigrina*, *Cephrenes augiades, Papilio aegeus aegeus* and *P. anactus*. Attendees were provided with a list of literature, online and society resources. Appendix III contains detail provided as handouts for the workshop.

Discussion & Recommendations

How do we identify hill-topping sites, and how do we know when a species is hill-topping?

The majority of species observed in this study are found breeding away from hill-tops, and many of them clearly do not require hill-tops for successful mate location. The assessment of whether they were hill-topping in this study was made on the basis of finding males congregating and forming territories on ridges. This is a broad definition which relies in part on identification of behaviours rather than habitat variables. It does pull in many species which are not obligate hill-topping species, but it also allows observers to define the hill-topping community present at any one site. It is also difficult to prove whether species are obligate hill-topping species, as within a population males may only assemble on the hill-top during part of their reproductive life, or a proportion of males may never hill-top. In a North American study Baughman *et al.* (1988) observed that in a closed population the majority of Bay Checkerspot *Euphydryas editha* males flew on the hill-top during their reproductive lifetime, but 20% of this male population still remained away from the hill-top. This would still leave a question mark as to whether this species is an obligate hill-topping species. Closed populations of butterfly species for which it is possible to assess either or both the age and reproductive status of the complete adult cohort are exceptional, which is why *E. editha* has been a popular research subject, as witnessed by numerous papers published by Paul Erlich and associated researchers. The Australian species in this study are not amenable to this type of assessment, and it will probably never be possible to assess the role of hill-topping in reproductive success of these species.

Because of the impossibility of determining if species are obligate hill-topping species it would be unrealistic to only focus on those species which are thought to have this status. The goal of this research is to provide tools for maintaining and assessing communities of hill-topping butterflies, and it would be impractical to restrict the definition of these communities to the very few species which are thought to be obligate hill-topping species.

Species not observed in the study

The species observed in this study are typical of those which are found in Hawkesbury Sandstone habitat around Sydney. There are surprisingly few published lists of butterflies found on hill-tops in the Sydney region to compare to this study. Common and Waterhouse (1972, 1981) list 17 species of butterfly observed at a hill-top in Killara including two rather rare species (*Acrodipsas brisbanensis* and *Ogyris ianthis*). It is not clear from the text as to when these observations were made, but it was presumably prior to 1972 when the first edition of this publication was released. Specimens of *O. ianthis* collected by G.A. Waterhouse from Killara were all taken prior to 1949, as are specimens collected by G. Daniels and G.D. Rushworth from this area (AM entomology collection). Rushworth subsequently visited this hill-top several times in the 1980s, and failed to observe these two rare species, although many of other species mentioned by Common and Waterhouse (1981) were still present, along with an additional ten species (Rushworth field diaries held in the AM entomology collection). Recent observations made by Hawkeswood (2007), at the same hill-top at East Killara added an additional species to the list (*Nacaduba biocellata biocellata*), bringing the total number of species observed on the hill-top to 28. This hill-top is the exception to most other areas around Sydney in that there has been a number of collectors observing the butterflies present over 80 years. It is of some concern then that adults of *O. ianthis* and *A. brisbanensis* are no longer present at this site, and this may be indicative of the damage caused by urbanisation, weed invasion and change in fire regimes.

A search on the AMS database indicated that approximately 135 species of butterfly are known from the broader Sydney Basin area. Some of these are rarely observed vagrants from the north, or are very localised and rarely encountered, and do not occur in Hawkesbury Sandstone habitats such as in our sample. However, some species are relatively abundant and have generalised distributions that take in much of the bushland regions in and around Sydney. Some of these species were not observed in this study, but would be expected to be observed if additional observation years were incorporated.

Species	Larval Habitat Requirements	Comments
Hesperiidae		
Dispar compacta	Various native Poaceae, including *Poa* sp.	Seen during the April workshop, data not included in main analysis
Hesperilla idothea	*Gahnia* spp.	males hill-top
Signeta flammeata	Poa tenera, *Tetrarrhena juncea* and grasses	males hill-top
Taractrocera papyria papyria	Many species of native and introduced Poaceae	not a hill-topping species, but usually common in grassy areas
Telicota ancilla	*Imperata cylindrica* (Blady grass) and other grasses, including introduced species	not a hill-topping species. *Telicota* species are very difficult to identify correctly.
Trapezites phigalioides	*Lomandra* spp.	Similar to *Trapezites phigalia*, but flies later in the season
Papilionidae		
Graphium eurypylus	Does not breed in Sydney	Sometimes comes south to Sydney, and is usually found on hill-tops
Pieridae		
Delias aganippe	Mistletoes, Cherry Ballart (*Exocarpus* sp.)	A strong hill-topping species, somewhat uncommon near the coast
Delias harpalyce	Mistletoes	A strong hill-topping species, active early in spring, and absent for most of summer.
Nymphalidae		
Danaus petilia	various Asclepiadaceae (native and introduced species)	
Geitoneura klugii	Poaceae, including some introduced grasses	Favours drier localities
Lycaenidae		
Acrodipsas brisbanensis	possibly inside nests of the Coconut ant *Papyrius nitidus*	Known almost exclusively from adults collected on hill-tops.
Acrodipsas cuprea	possibly inside nests of *Crematogaster* ants	Known almost exclusively from adults collected on hill-tops
C. consimilis	Restricted range of food plants	A strong hill-topping species, easily confused with *C. absimilis*.
Candalides absimilis	Broad range of food plants, but mostly on the developing shoots and flowers	Not a strong hill-topping species
Hypochrysops cyane	Various trees and mistletoe	Not a strong hill-topping species, known from very few specimens in the Sydney region
Hypochrysops delicia	Large trees of bipinnate *Acacia* species, especially black wattle *A. decurrens*, requires ant association (*Crematogaster* sp.)	A strong hill-topping species, often very localised, males hill-top late in the afternoon.
Lampides boeticus	Peas, particularly flowers and developing pods	A widely distributed species which also occurs in Africa, Europe & Asia
Ogyris abrota	Mistletoes	Not a hill-topping species
Ogyris genoveva	Mistletoes, requires ant association (*Camponotus* spp., usually *C. consbrinosus*)	A large and strong hill-topping species, often very localised
Ogyris ianthis	Mistletoes, requires ant association (*Froggettella kirbyi*)	A strong hill-topping species, very localised, throughout its distribution.
Ogyris olane	Mistletoes	A strong hill-topping species, somewhat uncommon near the coast
T. serpentata	Saltbushes	Hill-tops, but is very inconspicuous, usually found near the ground
Theclinesthes miskini miskini	*Acacia* spp.	Strong hill-topping species, can exhibit strong seasonal variation in markings

Table 5 Species not observed in this study which might be expected to occur in the surveyed habitats.

Table 5 lists species that might be expected to occur in the sampled habitats, but were not recorded in this study. Notable absences of species which would be expected to be common in the surveyed habitats include *Taractrocera papyria papyria*, *Delias harpalyce, Geitoneura klugii* and *Lampides boeticus*. Species which were absent, and which are of potential conservation significance include *Acrodipsas brisbanensis* and *Ogyris ianthis*.

Has loss and/or degradation of suitable habitat occurred at hill-tops in the surveyed area?

One of the project objectives was to demonstrate if loss and/or degradation of suitable habitat has contributed to changes in the fauna of hill-topping butterflies. Because there are no detailed historical records of butterfly communities at the surveyed hill-tops available for comparison it is not possible to make any clear statements in regard to this until further surveys are made.

Correlative comparisons of butterfly faunas with fire history and percentage vegetation cover must be treated with caution when trying to interpret whether anthropogenic change has affected the butterfly community. Broader topological factors may have far more influence on the structure of the hill-topping butterfly community than the above factors, and until a historical profile of the butterfly community is established it is not possible to confidently identify whether loss and/or degradation of habitat has affected hill-topping butterflies.

Reliability of observations

As reported in other studies on communities of Australian hill-topping butterflies (New & Britton, 1997), traditional standardised transect methods such as described by Pollard (1977) and others do not work very well for the purposes of conserving rare butterflies, as key species which define these butterfly communities are easily overlooked. Instead, the methodology in this study was to observe as many species as possible during the duration of the observation period within the limited area of the hill-top/ridge. This means that the collected abundance data is a subjective measurement, and can only be used with caution. Another factor which reduces the reliability of abundance data in studies of hill-topping butterflies is that it is very difficult to establish whether individuals are the same males resident in territories on the hill-top, or new males which are arriving and establishing territories.

One of the key stumbling blocks for assessing communities of butterflies at hill-topping localities is that many of the strongly hill-topping species prefer to establish territories on the highest points on the hill-top, which are usually the tops of eucalypts. Because of this they are usually impossible to collect for vouchers, and cannot be readily identified even with optical equipment such as spotting scopes. In addition to this, some of the most interesting and apparently rare species are small Lycaenidae, such as those in the genera *Acrodipsas* (Ant-blues) and *Hypochrysops* (Jewels). The morphological differences between *Acrodipsas* species are very subtle, and many species have only recently been recognised as distinct in recent years. The Sydney region is host for at least three species (*A. brisbanensis*, *A. cuprea* and *A. myrmecophila*), with only one species, *A. cuprea* being commonly collected from coastal hill-top localities. None of these butterflies were sighted during this study. This difficulty in confirming presence/absence of key hill-topping species must be taken into account when assessing hill-top communities. If the observer is confident that they can see all of the potential habitat on the hill-top, they should note this in their field diary. Otherwise the precautionary principle should be invoked, and the assumption made that these rare butterflies may occur at the site.

Observations on hill-tops which have been cleared or partially cleared may also be biased. Many hill-topping butterflies are much easier to observe in cleared habitats on the tops of hills, and this may erroneously cause observers to assume clearing or partial clearing is beneficial for these species. In some cases, butterflies are genuinely more active in open sunny areas, such as gaps in closed forest, or in the case of hill-tops in South Africa, areas free of dense plantations of introduced acacias (Lawrence and Samways, 2002).

This study highlights the importance of taking voucher specimens for later verification. Although the main field worker for the study (SG) is an experienced collector and observer of Australian butterflies there were a number of species observed in the field, collected then later examined that were found to be different species to what was noted in

the field diary. An example of the type of potential error which can occur include *Heteronympha banksii* collected and vouchered from Beckett's Forest (identified as *H. banksii* in the field), then later on the same day, another *Heteronympha* was collected and vouchered from Yoothamurra, which also was identified as *H. banksii* in the field. Later examination of the Yoothamurra specimen in the lab determined that this species was *H. paradelpha*. This was the only specimen of *H. paradelpha* collected during the study. A more positive example was the vouchering of a *H. mirifica* male. Males of this species are very similar to *H. merope* when seen flying, with only minor differences in behaviour. These minor differences alerted SG to a potential new species for the site, and specimen was vouchered, which enabled positive confirmation of the identity.

The proliferation of good quality and cheap digital cameras offers a partial solution to this issue. A good photograph of the underside, and if possible the upperside will often be adequate to resolve many identification problems. However, this is still unlikely to be of use if dealing with hill-topping species which often roost in the higher branches of trees on summits and ridges.

Whilst not all butterfly observers will want to collect specimens, either on ethical or on a practical basis, if a new area is being surveyed it is strongly recommended that specimens of potentially difficult to identify species (eg. many of the skippers, some of the Lycaenidae, Pieridae and Satyrinae) should be collected using appropriate methods such as those described in Braby (2000), and deposited as vouchers in a recognised collection such as at the AMS, or the Australian National Insect Collection. When doing this it is important to provide adequate information with the species, such as a precise location, date collected, and the name of the collector. Due consideration should be given to legalities such as having valid collecting permits when working in National Parks.

Assessment of Habitat for Hill-topping

One of the aims of this study was to identify features that make a hill-top attractive or functional for hill-topping species. In practice this is very difficult to do in anything other than a subjective manner. There were no obvious strong relationships when factors such as time since fire and percentage canopy cover were correlated against species diversity and abundance, although there was a tendency for increasing canopy cover to reduce the total abundance of butterflies at sites. A South African study by Lawrence and Samways (2002) indicated that percentage cover of vegetation was the most critical element determining the presence/absence of hill-topping species, and the presence of low densities of alien vegetation, such as introduced *Eucalyptus grandis* was less critical. High densities of either native or introduced vegetation acted to deter hill-topping behaviour, with open grassy hill-tops preferred, where sunlight could reach the ground surface. This is in contrast to much of the habitat surveyed in this study which were in open bushland, with plentiful basking opportunities near the ground surface even in areas of increasing percentage canopy cover. It is not clear in the Lawrence and Samways study how they eliminated the effects of differing vegetation surrounding their hill-tops; some of the changes in species composition and abundance observed by these researchers could easily be explained by absence of suitable breeding habitat adjacent to the hill-tops, or subtle topographic factors. However, as with the current study, it may be the case that the majority of observed butterfly species do not require specialised habitat for breeding, and have food plants which are broadly distributed in the habitat matrix surrounding the hill-tops.

This still leaves the question unanswered as to what is a "good" hill-top for butterflies in the Hawkesbury Sandstone regions to the north of Sydney. As mentioned earlier in the discussion, habitat alone is not enough, and direct observations of butterfly activity is required. Although the fauna of individual hill-tops in Sydney is poorly known, there are good overall records of what species could potentially be present on hill-tops in Sydney, especially when collection data such as that in the AMS is available. If a hill-top is appropriately assessed for presence/absence of butterfly species, this can be compared to what would be expected to occur in this region in Sydney. In this case, we would have identified the standout site with the highest values for hill-topping butterflies to be Hornsby Heights.

Sampling effort required to adequately survey a hill-top

From looking at the species accumulation curves generated in this study, it was possible to estimate how many visits to a site were required to observe the butterfly fauna present at sites. Figure 9 plots the average cumulative percentage of the total fauna seen at a site against the number of visits. This indicates that for most sites, three to four visits would result in over 90% of the total number of species present at that site being observed. To capture variation across the season, it would be recommended to visit at least once in October and February. January and March are also recommended months for survey work.

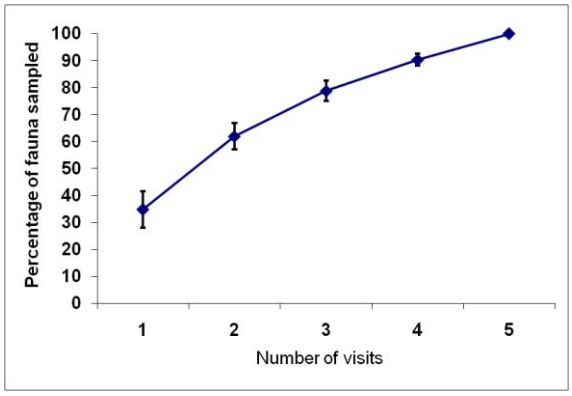

Figure 9 The number of visits required to observe a percentage of the butterfly fauna.

Observation conditions

Butterflies are very sensitive to immediate climatic conditions, and to time of day, which limits the opportunities for observation. This was not explicitly tested in this study, but from the combined field experience of the report authors and direct observation of butterfly behaviour during this field season it was possible to summarise the conditions under which most observations could be made. These are listed in Table 6 in the report recommendations.

Seasonality

Because this study only covered a single season it is difficult to comment on seasonal conditions which may have affected the observations. Because butterflies and other invertebrates are exothermic organisms with their activity patterns largely dependent on external temperatures, transient weather patterns will greatly affect presence/absence observations in the field. A cloudy period will often result in adult butterflies settling on or under vegetation where they are invisible to the observer.

Field workers in this study made detailed notes on weather conditions at the time of observation, but it is not possible to make generalisations based on these notes as to the reliability of observations at each site.

The overall summer season of 2007/08 was comparatively cool and wet, which seemed to suit some species. One species which clearly seemed to benefit was the Orange Ringlet *Hypocysta adiante* (Nymphalidae: Satyrinae). Like many of the Satyrinae the larvae of this species feed on grasses. Grass growth in bushland areas was strongly promoted by the increased summer rainfall, and in some sites in late summer this small butterfly was very abundant. Because prior baseline data is lacking it is not clear whether this is a regular event for the surveyed sites, but in the opinion of the report authors this represents a strong response to the climatic conditions of the study period.

In contrast, some species did not appear to thrive in the cool wet conditions. One example is the small Two Spotted Lineblue *Nacaduba biocellata biocellata*, which is normally abundant in most eastern Australian dry sclerophyll habitats over summer. This species was only sighted once mid-study. It should be emphasised that these changes in abundance are temporary, and the capacity of populations of butterflies and other invertebrates to recover from adverse conditions is great.

Education

The over-subscription, and the enthusiastic response to the two community workshops run during this study suggests that there is a significant demand for future workshops of a similar nature. It is difficult to establish at this stage what the long term benefits are of having a community who is partially educated to observe and understand butterflies in the Australian habitat. As mentioned above, there is no ready outlet for information gathered by community members. However, this education and awareness may result in early recognition of significant habitat prior to inappropriate development occurring. Persons engaged in active habitat restoration may be more likely to include plants which are suitable for enhancing butterfly populations. The increased awareness of the significance of invertebrate conservation will hopefully result in increased

funding and charitable support to conservation projects.

The level of knowledge imparted from the workshops would not be adequate for attendees to immediately make reliable observations of butterflies, but was sufficient to enable them to use available resources to gain the necessary skills. As with identification of any group of organisms, the ability to make correct identifications, especially from observation only, is something that comes with both practice and application. It is also possible that a level of pre-existing aptitude or motivation is required. Many butterfly identifications based on observation of live insects are made from gestalt rather than by using a narrow set of either morphological or behavioural characters. In this respect, the field identifications of butterflies use something similar to what bird observers call a bird's "giz", which relies on using an indefinable set of general characters to recognise individual species. This is something that requires many careful observations followed by validation of identifications.

Recommendations for future work

This study covered sandstone ridges in the north-west of Sydney in a small part of the total HNCMA region. The breadth of the HNCMA region means that without substantial funding it is not possible to sample more habitats. The HNCMA includes montane regions such as the parts of the Blue Mountains, and areas which have completely different vegetation communities and soil types to the sandstone habitats sampled here. These areas will have very different butterfly communities, and it would be strongly desirable to have representative baseline data from some of these other different habitats. Once a series of hill-top locations have been identified, it may be possible to flag these for repeat visits from keen and trained community observers.

Recommendation 1: Seek additional funding to survey hill-tops in other regions of the HNCMA

The community workshops raised a significant issue with reporting observational butterfly data from the public, HNCMA and Parks personnel. The DECC Atlas of NSW Wildlife (DECC, 2008b) is available for input of observational data, but it seems to have been little used by invertebrate observers, with 324 records of 32 insect taxa compared to birds (for example), which have 2,498,495 records of 714 taxa (as of May 2008). There would seem to be a definite need to increase the input of invertebrate observations, especially for groups such as butterflies, which can for the most part be reliably recorded at the species level. It is not clear why there are so few invertebrate observations in the Atlas. One immediate drawback in regards to recording hill-topping behaviour is that there is no way of searching for this aspect of the data through the public search portal of the Atlas, as searches are limited to taxon and region.

Other research and community groups have investigated the possibilities of increasing community involvement in collecting information on invertebrates (eg. AUSRIVAS, 2008; BugWise, 2008), but institutions are usually not willing to support the ongoing costs of database maintenance when the data collected does not directly support research and collection development priorities within the institution. A butterfly atlas is available for Victoria (VBFP, no date), but this is a static cd-rom database rather than a resource to which users can add their own observations. From this it seems there is a requirement for either development and ongoing maintenance of a database which is available for recording butterfly and other invertebrate data, or adaptation/promotion of the existing DECC Atlas of NSW Wildlife to increase the input of data.

Recommendation 2: Promote and facilitate input of butterfly observational data in the DECC Atlas of NSW Wildlife.

One of the key aims of this study is to provide DECC and HNCMA with guidelines as to how to survey hill-tops for butterflies to determine suitable habitat. Table 6 is a list of what we consider to be the minimal requirements for assessment of habitat on hill-tops in temperate locations in Australia including the HNCMA.

Recommendation 3: Survey Guidelines: minimum requirements for hill-top survey of butterflies – Listed in Table 6

One of the aims of this project was to identify key hill-tops within the surveyed region. As previously stated, one site in particular stood out as a diverse location for butterflies, including hill-topping

species (Hornsby Heights). Other studies of hill-tops have found that repeating surveys over subsequent seasons can greatly enrich the data set, and provide information on change in butterfly populations associated with habitat change and climate change (Britton et al. 1995). This data can also be used to validate species accumulation curve models such as that presented here, and provide a solid baseline for comparisons to other survey data.

In order to identify the effects of loss and/or degradation of suitable habitat it is also useful to start with a butterfly community which has the potential to demonstrate these effects. Because Hornsby Heights is relatively rich in the number of butterfly species it should be the most sensitive to intentional and unintentional alteration to the hill-topping habitat, and changes in the habitat will be reflected in the butterfly community.

Recommendation 4: Continue monitoring of the Hornsby Heights location to build on the existing data set

	Recommendations
Operator Qualifications	
Skills	Operators are able to carry out accurate field identifications and observations
	Operators are willing and able to collect voucher specimens when appropriate
Frequency of Observations	
Season	Observers visit at least once in October and in either January/February/March
Species accumulation	Observers visit a site at least three times at the above times of year in appropriate weather conditions
Observation Conditions	
Hill-top structure	Most areas are clearly visible to the observer, including tops of trees
Temperature	Greater than 22ºC, less than 35 ºC
Humidity	Not critical except at very high temperatures, when low humidity will restrict activity
Cloud cover	Low or no cloud is generally preferable, although in higher temperatures activity will still occur during overcast periods
Wind	Wind speeds less than 2 m/s – higher wind speeds do not completely prevent activity, but will make observation difficult
Observation period	One hour per site, depending on butterfly activity, changing weather conditions and operator experience
Time of day	In hot weather, between mid-morning and midday; some species active only in late afternoon

Table 6 Survey Guidelines: minimum requirements for adequate survey of butterflies on hill-tops in the HNCMA

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Appendices

Appendix I

Site Data sheets

Appendix II

Species accounts for butterflies observed in this study

Appendix III

Handouts presented at workshops

Appendix I Field Data Sheets

Date:	/ /	Time	From: To:	
Weather conditions:				
Temperature range:	°C	Av. Wind Speed: km/hr	Relative Humidity: %	Heat Stress:
Site:			Collection event code:	
Location:				
GPS Co-ordinates:			Elevation:	Aspect:
Habitat:				

Host plants:

Species observed:

Species name	Estimated abundance	Condition	Behaviour	Flight pattern

Appendix I Field Data Sheets

Species name	Estimated abundance	Condition	Behaviour	Flight pattern

Appendix II

Species accounts for butterflies observed in this study:

Unless specified, general species information in this section is derived from the literature reviews in Braby, 2000, where the primary literature references are listed. Readers who wish to identify and compare the listed butterfly species here are encouraged to use either Braby (2000) or Braby (2004). Information on food plants occurring in the survey region is derived both from the site assessments and from records in the Hornsby Online Herbarium (2008) and from a spatial search of the PlantNET (2008) database at the Royal Botanic Gardens.

Hesperiidae

Trapezitinae

Dispar compacta
Dispar Skipper, Barred Skipper
Months sighted: April
Percentage of Sites occupied: 7%
Hill-topping species: Yes
Conservation Significance: None
This species behaves somewhat similarly to the nymphalid butterflies *Vanessa itea* and *V. kershawi* in that it often hill-tops, but it does not not seem require hill-tops for successful mating behaviour. Detailed life-history data is lacking, but larvae appear to have a broad host range, feeding on grasses (*Poa* spp.), sedges (*Gahnia* spp.) and mat rushes (*Lomandra* spp.) and possibly including some introduced species, as the skipper occurs in urban regions as well as in native bushland.

Mesodina halyzia
Eastern Iris-Skipper
Months sighted: October to March
Percentage of Sites occupied: 80%
Hill-topping species: No
Conservation Significance: None
A moderately common species associated with woodland and heath areas where the larval food plants occur (*Patersonia* including *P. glabrata* and *P. sericea* which occur in the Hornsby region).

Toxidia doubledayi
Lilac Grass-skipper, Doubleday's skipper
Months sighted: February to March
Percentage of Sites occupied: 13%
Hill-topping species: No
Conservation Significance: None
A common species, with grass-feeding larvae. Food plant details are lacking, although a record of larvae feeding on the rainforest grass *Oplismenus* sp. exists.

Toxidia parvulus
Banded Grass-skipper, Parvula Skipper
Months sighted: November, March
Percentage of Sites occupied: 13%
Hill-topping species: No
Conservation Significance: Localised
This species is generally localised and infrequently encountered, and this was reflected by the few sightings made in this study. Larvae feed on grasses, but further details are lacking.

Toxidia peron
Dingy Grass-skipper, Peron's Skipper
Months sighted: September to March
Percentage of Sites occupied: 67%
Hill-topping species: Yes
Conservation Significance: None
The most commonly encountered *Toxidia* species, and the only common one which hill-tops, found in weedy urban areas, suburban gardens and in bushland. Larvae feed on a broad range of monocots, including *Gahnia* spp., *Dianella* sp., *Poaceae*, *Lomandra* spp. They probably feed on some introduced grass species in the Hornsby area, and were observed by SG ovipositing on a species of grass at Metheringham's Hill. They are known to feed on Buffalo Grass *Stenotaphrum secundatum* elsewhere. Males often make territories next to open areas which they defend from conspecifics and from other insects.

Trapezites eliena
Orange Ochre, Eliena Skipper
Months sighted: September to November, January to March
Percentage of Sites occupied: 27%
Hill-topping species: Yes
Conservation Significance: Localised
A broadly distributed *Trapezites* species, but often with localised populations. Probably has a

spring brood and an autumn brood. Larval food plants are *Lomandra* spp., including *L. longifolia*, *L. confertifolia*, *L. filiformis*, *L. multiflora* which occur in the Hornsby area.

Trapezites iacchoides
Silver-studded Ochre, Iacchoides Skipper
Months sighted: September to October
Percentage of Sites occupied: 13%
Hill-topping species: Yes
Conservation Significance: Localised
A species strongly associated with sandstone habitats, and with localised distributions. Probably occurs in more locations than collections indicate. The short adult flight period in September and October may result in a lack of records of this skipper. Larvae are on *Lomandra* spp., including *L. longifolia*, although other species may be used.

Trapezites petalia
Black-ringed Ochre, Common White-spot Skipper
Months sighted: November, February to March
Percentage of Sites occupied: 13%
Hill-topping species: Yes
Conservation Significance: Localised
This species has a broad, but disjunct distribution, and is infrequently seen in the Sydney basin. Males will also form territories in cleared areas. Larvae feed on *Lomandra* spp., including *L. longifolia*, *L. filiformis* and *L. multiflora*.

Trapezites phigalia
Heath Ochre, Phigalia Skipper
Months sighted: October to November
Percentage of Sites occupied: 20%
Hill-topping species: Yes
Conservation Significance: Localised
Like the Iacchoides Skipper, this species has a short early season flight period, but a broader range of habitat preferences, occurring in mostly dry sclerophyll forest. The adults can sometimes be seen hill-topping in the company of *T. iacchoides*. Larvae feed on *Lomandra* spp., including *L. filiformis*, *L. glauca*, *L. multiflora*, and *L. obliqua*, which occur in the Hornsby area.

Trapezites praxedes
Southern Silver Ochre, Praxedes Skipper
Months sighted: January to March
Percentage of Sites occupied: 60%
Hill-topping species: No
Conservation Significance: Localised
Relatively common in this survey in late summer and autumn, usually in dry sclerophyll on sandstone. Braby (2000) comments that this species is normally uncommon and local. Larval food plants are *Lomandra* spp., including *L. confertifolia*, *L. longifolia* and *L. obliqua*.

Trapezites symmomus symmomus
Splendid Ochre, Symmomus Skipper
Months sighted: December to March
Percentage of Sites occupied: 73%
Hill-topping species: No
Conservation Significance: None
The largest *Trapezites*, and one of the most commonly encountered in habitats ranging from rainforest through to heathland, including urban gardens. Larvae feed on *Lomandra*, including *L. longifolia*, *L. hysterix*, *L. filiformis*, and *L. obliqua*. Larval populations are often localised, usually preferring food plants located in partial shade, especially in gullys and along creek lines.

Pyrginae

Netrocoryne repanda repanda
Bronze Flat, Eastern Flat
Months sighted: November to December
Percentage of Sites occupied: 13%
Hill-topping species: Yes
Conservation Significance: None
Infrequently encountered in this study. Males will hill-top in open sclerophyll habitats. Adults are usually only active during the morning, which may have reduced the number of sightings. Larvae feed on a broad range of woody plants, including some rainforest species. Likely candidates in the Hornsby region include Black Wattle *Callicoma serratifolia*, Blueberry Ash *Elaeocarpus reticulatus*, Native Quince *Alectryon subcinereus*, and Kurrajong *Brachychiton populneus*. SG has bred larvae from Black Wattle near Cherrybrook.

Hesperiinae

Ocybadistes walkeri sothis
Green Grass-dart

Months sighted: September to October, December to March
Percentage of Sites occupied: 60%
Hill-topping species: No
Conservation Significance: None
A very common skipper found in suburban gardens and other areas of non-native vegetation as well as bushland sites, where the larvae feed on common introduced grasses. Native food plants include Blady Grass *Imperata cylindrica* which can be very common in disturbed areas. For a summary of the many food plants see Braby (2000)

Suniana lascivia lascivia
Dingy Grass-dart
Months sighted: March
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: None
A common skipper found in suburban gardens and other areas of non-native vegetation as well as bushland sites. Larvae feed on Blady Grass *Imperata cylindrica*. Possibly overlooked at some sites due to its small size and inconspicuous habits.

Papilionidae

Graphium macleayanus macleayanus
Macleay's Swallowtail
Months sighted: January to March
Percentage of Sites occupied: 20%
Hill-topping species: Yes
Conservation Significance: None
This strong flying species is usually associated with rainforest and montane habitats, so was not often seen around the dry sclerophyll habitats surveyed in this study. Larvae feed on the foliage of trees in the families Lauraceae, Winteraceae and Moniamiaceae, and in the Hornsby area the likely food plants are Sassafras *Doryphora sassafras* and also the introduced Camphor Laurel *Cinnamomum camphora*.

Graphium sarpedon choredon
Blue Triangle
Months sighted: September, February
Percentage of Sites occupied: 20%
Hill-topping species: Yes
Conservation Significance: None
This species would naturally occur in rainforest, or on the edge or rainforest habitats, however larvae readily feed on the foliage of the introduced Camphor Laurel *Cinnamomum camphora*, and adults are commonly seen in urban and bushland areas where this tree occurs. Males often hill-top in the company of *G. macleayanus*. Native hosts in the Hornsby region are also likely to belong to the families Lauraceae.

Papilio aegeus aegeus
Orchard Swallowtail
Months sighted: October, December to March
Percentage of Sites occupied: 73%
Hill-topping species: No
Conservation Significance: None
A common butterfly wherever there is *Citrus* grown, with both native and introduced *Citrus* used as food plants by the larvae. Other native plants in the family Rutaceae found in the Hornsby area may act as larval hosts, including *Eriostemon australasius, Leionema dentatum*, *Philotheca* spp., and *Zieria smithii*. Introduced Rutaceae may also be used, such as Mexican Orange *Choisya ternata*.

Papilio anactus
Dainty Swallowtail, Dingy Swallowtail
Months sighted: October, December to March
Percentage of Sites occupied: 67%
Hill-topping species: Yes
Conservation Significance: None
A common butterfly wherever there is *Citrus* grown, with both native and introduced *Citrus* used as food plants by the larvae.

Pieridae

Coliadinae

Eurema hecabe hecabe
Large Grass-Yellow
Months sighted: January
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: None
This species appears to be migratory, although exact details of movements are lacking. It is an infrequently observed butterfly in Sydney, and does not breed this far south.

Eurema smilax
Small Grass-yellow
Months sighted: October
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: None
The most common *Eurema* in Sydney, appears to be migratory over much of its large Australian range. The species is known to breed in the Sydney region where larval food plants include the introduced *Cassia fistula*.

Pierinae

Appias paulina ega
Common Albatross
Months sighted: February
Percentage of Sites occupied: 7%
Hill-topping species: Yes
Conservation Significance: None
This species is non-resident, and adults are not seen as far south as Sydney every year.

Belenois java teutonia
Caper White
Months sighted: September to November
Percentage of Sites occupied: 33%
Hill-topping species: No
Conservation Significance: None
A migratory species usually seen in late spring/early summer. The majority of individuals seen in Sydney fly in a northerly direction, and may be present in very large numbers. The species is non-resident with larvae on plants in the family Capparaceae which occur in rainforest and frost-free inland areas north and north-west of Sydney.

Delias nigrina
Black Jezebel, Common Jezebel
Months sighted: October to November, January to March
Percentage of Sites occupied: 87%
Hill-topping species: Yes
Conservation Significance: None
The most common *Delias* species occurring in Sydney, often flying in autumn and sometimes even winter. Like other *Delias* spp. males will congregate on hill-tops, but this behaviour does not seem to be as strongly developed in *D. nigrina*. Larval food plants are many species of mistletoes (Loranthaceae), including several *Amyema* spp., *Dendrothoe vitellina* and *Muellerina eucalyptoides*. Other food plants are listed in Braby (2000).

Pieris rapae rapae
Cabbage White
Months sighted: October, February
Percentage of Sites occupied: 20%
Hill-topping species: No
Conservation Significance: None
An introduced butterfly in Australia, and a pest of cultivated Brassicaceae. In bushland areas it is often associated with disturbed weedy areas with turnip weed and other *Brassica*.

Nymphalidae

Acraeinae

Acraea andromacha andromacha
Glasswing
Months sighted: February to March
Percentage of Sites occupied: 13%
Hill-topping species: Yes
Conservation Significance: None
A non-resident species in Sydney, often very common on hill-tops, where it can make observation of other butterflies difficult. Larvae feed on native and introduced Passifloraceae, excluding the common domestic passionfruit *Passiflora edulis*. It does not seem to regularly breed in the Sydney area.

Danainae

Danaus plexippus
Wanderer, Monarch
Months sighted: November, February to March
Percentage of Sites occupied: 20%
Hill-topping species: No
Conservation Significance: None
This species became established in Australia in the late 1800s after introduction of the larval food plants enabled the butterfly to breed here. Larval food plants are all introduced species in the family Asclepiadaceae.

Nymphalinae

Junonia villida calybe
Meadow Argus

Months sighted: October to December, February to March
Percentage of Sites occupied: 47%
Hill-topping species: No
Conservation Significance: None
A very common butterfly in Australia, often associated with weedy open habitats, where larvae feed of a wide variety of small herbaceous plants, including many introduced weed species (see Braby, 2000 for a list of these).

Vanessa itea
Australian Admiral, Yellow Admiral
Months sighted: September to November, January, March
Percentage of Sites occupied: 33%
Hill-topping species: Yes
Conservation Significance: None
Common butterfly often found in damp weedy habitats where the larval food plants in the family Urticaceae occur. Larval food plants in the Sydney region include the native pellitory *Parietaria debilis* and nettle *Urtica incisa*, as well as the introduced Asthma Weed *P. judica*, Baby's Tears *Soleirolia soleirolii* and nettle *Urtica urens*. Adults often defend hill-top territories in late afternoon along with *V. kershawi*.

Vanessa kershawi
Australian Painted Lady
Months sighted: September to November, January to February
Percentage of Sites occupied: 93%
Hill-topping species: No
Conservation Significance: None
A very common species found in most Australian habitats. Adults establish territories in open areas including hill-tops, but the species does not exhibit strong hill-topping behaviour as does *V. itea*. Larvae feed on herbaceous Asteraceae, including some introduced species (see Braby, 2000 for list of species).

Charaxinae

Polyura sempronius
Tailed Emperor
Months sighted: January
Percentage of Sites occupied: 7%
Hill-topping species: Yes
Conservation Significance: None
A spectacular fast flying species which is found over a large area of Australia, although rarely appearing in large numbers. Larvae feed on many *Acacia* spp., and some related Mimosaceae, as well as Kurrajong (*Brachychiton populneus*), and many other woody plants, some of which occur in suburban gardens (see Braby, 2000 for a list).

Satyrinae

Argynnina cyrila
Forest Brown, Cyril's Brown
Months sighted: October
Percentage of Sites occupied: 7%
Hill-topping species: Yes
Conservation Significance: None
A spring butterfly, with adults not appearing after late October. Larvae appear to feed on native grasses in the genus *Poa*, and may possibly occur on wiry rice grass *Tetrarrhena juncea*.

Geitoneura acantha
Eastern Ringed Xenica
Months sighted: January to March
Percentage of Sites occupied: 53%
Hill-topping species: No
Conservation Significance: None
Common in bushland areas, usually in areas with higher rainfall where the larvae feed on soft grasses on southern aspects. Larval food plants include *Microlaena stipoides* and *Poa* spp.

Heteronympha banksii banksii
Bank's Brown
Months sighted: March
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: None
A late season brown which is usually associated with wet sclerophyll and rainforest areas. Larvae on native grasses including *Poa* spp., but have also been recorded on sedges including *Gahnia melanocarpa* and *Carex longebrachiata*.

Heteronympha merope merope
Common Brown
Months sighted: October to April
Percentage of Sites occupied: 93%
Hill-topping species: Yes
Conservation Significance: None

The most common large brown in Sydney. Larvae feed on introduced and native grass species (see Braby, 2000 for list). Males appear in October, with females flying a few weeks later in November.

Heteronympha mirifica
Wonder Brown
Months sighted: November
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: Localised
A rainforest species, with larvae feeding on *Oplismenus* spp.. Females usually do not leave the damp gullies where the food plant occurs, but males will enter open areas, and fly considerable distances along ridge tops. Because of these restrictive habitat preferences this species is not commonly seen in the Sydney region. SG has observed large numbers of this species in gullies near Cherrybrook.

Heteronoympha paradelpha
Spotted Brown
Months sighted: March
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: Localised
One of the most localised species of *Heteronympha*, found in a variety of wet sclerophyll habitats on the east coast. Larval food plants are grasses including *Microlaena stipoides* and *Poa tenera*.

Hypocysta adiante
Orange Ringlet
Months sighted: October to April
Percentage of Sites occupied: 47%
Hill-topping species: No
Conservation Significance: None
This species is usually associated with coastal dry sclerophyll forests, including tropical savannahs. Larvae feed on Kangaroo Grass *Themeda triandra*, but may also use *Imperata cylindrica*.

Hypocysta euphemia
Rock Ringlet
Months sighted: October
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: Localised
As the common name suggests this species is associated with rocky areas, such as sandstone habitats around Sydney. Few individuals are usually seen when this species is present. Larvae feed on grasses, but specific details are lacking.

Hypocysta metirius
Brown Ringlet
Months sighted: September to October, January to March
Percentage of Sites occupied: 33%
Hill-topping species: Yes
Conservation Significance: None
This species is usually the most commonly encountered ringlet in damp coastal areas around Sydney, although *H. pseudirius* often replaces it in drier localities, and the two species can often be collected flying at the same locality. This species seems to persist in weedy urban parkland and gullies. Larvae on grasses and sedges (see Braby, 2000 for a list).

Hypocysta pseudirius
Grey Ringlet
Months sighted: September to April
Percentage of Sites occupied: 80%
Hill-topping species: Yes
Conservation Significance: None
Usually rarer than the similar *H. metirius*, this species was common at the surveyed sites in this study. The species occurs in much drier habitats than *H. metirius*, but the two often overlap. Larvae on grasses, but specific details are lacking.

Tisiphone abeona abeona
Varied Sword-grass Brown, Sword-grass Brown
Months sighted: October to April
Percentage of Sites occupied: 73%
Hill-topping species: Yes
Conservation Significance: None
The males of this species hill-top in the mornings, flying away from the larval food plants (Sword Sedges, *Gahnia* spp., species listed in Braby, 2000) which are nearly always located in gullies. They return to areas around food plants later in the day where they patrol for females. Several races of this butterfly are endangered in other areas of Australia where clearing has removed swampy areas, but the Sydney populations appear to be healthy.

Ypthima arctous
Dusky Knight, Dingy Ring
Months sighted: November, January to March
Percentage of Sites occupied: 33%
Hill-topping species: No
Conservation Significance: None
This species is usually found in open sclerophyll woodland where the larval food plant (Blady Grass, *Imperata cylindrica*) occurs.

Lycaenidae

Polyammatinae

Candalides acasta
Blotched Dusky-blue, Blotched Blue
Months sighted: October to March
Percentage of Sites occupied: 47%
Hill-topping species: Yes
Conservation Significance: None
A common butterfly in Sydney bushland, usually found flying near its larval food plants of Dodder Laurel *Cassytha* spp, especially *C. glabella*.

Candalides cyprotus cyprotus
Copper Pencilled-blue, Cyprotus Blue
Months sighted: September to October
Percentage of Sites occupied: 20%
Hill-topping species: Yes
Conservation Significance: Localised
A spring active species, often very localised. The food plant in the Sydney region is probably Variable Smoke-bush *Conospermum taxifolium*, but this requires confirmation, as the species has been known to feed on flowers and new growth of *Grevillea* and *Hakea* species as well. The species has a very broad distribution in many different habitats, but seems to be vulnerable to disturbance, and is absent from sites which have been frequently burnt.

Candalides hyacinthina hyacinthina
Varied Blotched Blue
Months sighted: September to April
Percentage of Sites occupied: 87%
Hill-topping species: Yes
Conservation Significance: None
The most common of the dodder laurel feeding *Candalides* species, occurring almost wherever the food plants (*Cassytha* spp.) are found. Males hill-top, but will also establish territories along open tracks in bushland. The larval food plants in the survey region is probably *C. pubescens*.

Candalides xanthospilos
Yellow-spotted Blue
Months sighted: October, December, February
Percentage of Sites occupied: 27%
Hill-topping species: No
Conservation Significance: None
This distinctive species occurs in the vicinity of its larval food plants of Riceflowers *Pimelea* spp. Larval food plants in the survey region probably include *P. ligustrina* and *P. linifolia*.

Nacaduba biocellata biocellata
Two-spotted Line-blue, Double-spotted Line-blue
Months sighted: January
Percentage of Sites occupied: 7%
Hill-topping species: Yes
Conservation Significance: None
This small butterfly is often mistaken for rarer hill-topping species in the genus *Acrodipsas*, but when seen up close it cannot be confused with these other butterflies. It is usually a common species in sclerophyll habitats, and it is unusual that it was not reported more frequently in this study. The larvae feed on developing flower buds of *Acacia* spp. The species appears to hill-top, but often males are forming territories around the tops of acacias rather than hill-topping.

Neolucia agricola
Fringed Heath-blue, Fringed Blue
Months sighted: September to October
Percentage of Sites occupied: 47%
Hill-topping species: No
Conservation Significance: None
A spring species common where larval food plants occur, such as low-growing peas (Fabaceae) including species of *Bossiaea*, *Daviesia* and *Pultenaea*.

Prosotas felderi
Small-tailed Line-blue
Months sighted: January to March
Percentage of Sites occupied: 27%
Hill-topping species: No
Conservation Significance: None
This species can be very abundant in wet coastal habitats, and the presence of adults in the surveyed sites is possibly an indication of how a

wet summer can affect the abundance of some insects. The larvae feed on flowers and developing fruit of *Acacia* spp., *Macadamia integrifolia*, *Alectryon coriaceus* and *Cupaniopsis anacardioides*, as well as some introduced plant species (see Braby, 2000 for a full list).

Sahulana scintillata
Glistening Blue
Months sighted: February
Percentage of Sites occupied: 13%
Hill-topping species: Yes
Conservation Significance: None
This species is noteworthy in that it seems to be moving south along the coast of NSW. It has been infrequently observed in the Sydney region, with few specimens recorded south of Newcastle, although it is more common in coastal areas further north in NSW. Larval food plants include *Alectryon coriaceus* and *Cupaniopsis anacardioides.*

Zizina labradus labradus
Grass Blue
Months sighted: October to April
Percentage of Sites occupied: 87%
Hill-topping species: No
Conservation Significance: None
Possibly the most abundant butterfly in Australia, this species occurs in almost all urbanised and agricultural regions, as well as in bushland areas. Foodplants are herbaceous legumes (Fabacae), such as introduced clovers and medics, as well as many native peas (see Braby, 2000 for a list).

Theclinae

Jalmenus evagoras evagoras
Imperial Hairstreak
Months sighted: December to March
Percentage of Sites occupied: 20%
Hill-topping species: No
Conservation Significance: None
The most common of the *Jalmenus* species on the east coast, forming conspicuous colonies on *Acacia* spp., where all life-history stages may often be present in the same area. This species has an obligate relationship with ants in the genus *Iridomyrmex*, with several species of ants attending eggs, larvae and pupae on the food plants. Colonies can often be highly localised, with only one or two trees utilised in an area of potentially suitable trees. Larvae and pupae were located on trees at the Galston and Wiseman's Ferry sites. Acacias likely to be used in the survey area include *A. decurrens*, *A. floribunda*, *A. implexa*, *A. irrorata* and *A. parramattensis*. Unlike many other lycaenid species the larvae are active feeders during daylight.

Paralucia aurifer
Bright Copper
Months sighted: December
Percentage of Sites occupied: 7%
Hill-topping species: No
Conservation Significance: None
The most commonly encountered species in the genus *Paralucia*. A single unconfirmed sighting was made in this study. The species is not uncommon in areas around Sydney where the larvae feed on *Bursaria spinosa* and *Pittosporum multiflorum*. The species has an obligate relationship with strong-smelling ants in the genus *Anonychomyrma* which attend larvae whilst they feeding at night on the food plants.

Butterfly Workshop Notes
Morning Presentation:

Butterfly Conservation: Butterflies as invertebrate flagships

I) Importance of invertebrates

- Represent the greatest species diversity
- Key components of ecosystems
- Sensitive to change in environment
- Important roles (eg. pollination, recycling, herbivores, parasites and predators)
- Aesthetically attractive

II) Problems with invertebrate conservation

- Perception – “unimportant”, or simply not seen by humans
- Four animals in one - complex life histories
- Variable populations
- Not enough people making observations
- Lack of knowledge- we don’t know what is happening

III) How to monitor and observe butterflies – collecting Information.

- Butterfly biology & life history
- Butterfly behaviour
- Butterfly diversity
- Hill-tops
- Food plants
- Field notes
- Equipment and collecting
- Photography

Butterfly Hill-topping Project

Useful Resources

Books

Braby, M.F. 2000. The butterflies of Australia: their identification, biology and distribution. CSIRO Publishing, Collingwood, Victoria; xx + 976 pp.

Braby M.F. 2004. The Complete Field Guide to the Butterflies of Australia. CSIRO PUBLISHING, Collingwood, Victoria, 352 pp.

Fairley, A. & Moore P. 2000. Native Plants of the Sydney District, An Identification Guide. Roseville, NSW; Kangaroo Press.

Robinson, L. 1994. Field Guide to the Native Plants of Sydney. Kangaroo Press, Kenthurst.

Dunn, K.L. and Dunn, L.E. 1991. Review of Australian Butterflies: distribution, life history and taxonomy. Parts 1-4. Privately published by the authors, Melbourne.

Common, I.F.B. and Waterhouse, D.F. 1981. Butterflies of Australia. Revised edition. Angus and Robertson, Sydney.

New, T.R. 1991. Butterfly Conservation. Oxford Univ. Press Australia; 224 pp.

Web Resources

Hornsby Herbarium - http://wwwopac.hornsby.nsw.gov.au/herbarium/

Royal Botanic Gardens - PlantNET - http://plantnet.rbgsyd.nsw.gov.au/

South Australian Butterflies - R. Grund - http://users.sa.chariot.net.au/~rgrund/

Victorian Butterflies – Museum Victoria - Atlas of Victorian Butterflies - http://museumvictoria.com.au/bioinformatics/butter/

Don Herbison – Australian butterfly larvae - http://www-staff.it.uts.edu.au/~don/larvae/butter.html

ABRS – Australian Faunal Directory - http://www.environment.gov.au/cgi-bin/abrs/fauna/tree.pl?pstrVol=PAPILIONOIDEA&pintMode=1

Bugwise – (In development) - http://bugwise.maxdesign.com.au/

Societies

The Society for Insect Studies - http://www.duttcom.com/InsectStudies/

Butterfly and Invertebrates Club, SE QLD - http://www.boic.org.au/

Entomological Society of NSW - http://entsocnsw.netfirms.com/

Entomological Society of Victoria - http://home.vicnet.net.au/~vicento/vicent.htm

Collections

Australian National Insect collection –Canberra - http://anic.ento.csiro.au/

Australian Museum - Sydney - http://www.austmus.gov.au/

Museum Victoria – Melbourne - http://www.museumvictoria.com.au/

South Australian Museum – Adelaide - www.samuseum.sa.gov.au/

Equipment & Books

Australian Entomological Supplies - www.entosupplies.com.au/

Australian Museum Bookshop - http://www.amonline.net.au/shop/

Project Affiliates

Hawkesbury Nepean Catchment Management Authority - http://www.hn.cma.nsw.gov.au/

Natural Heritage Trust - http://www.nht.gov.au/

Department of Environment and Climate Change NSW - http://www.environment.nsw.gov.au/index.htm

Australian Museum - Sydney - http://www.austmus.gov.au/

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