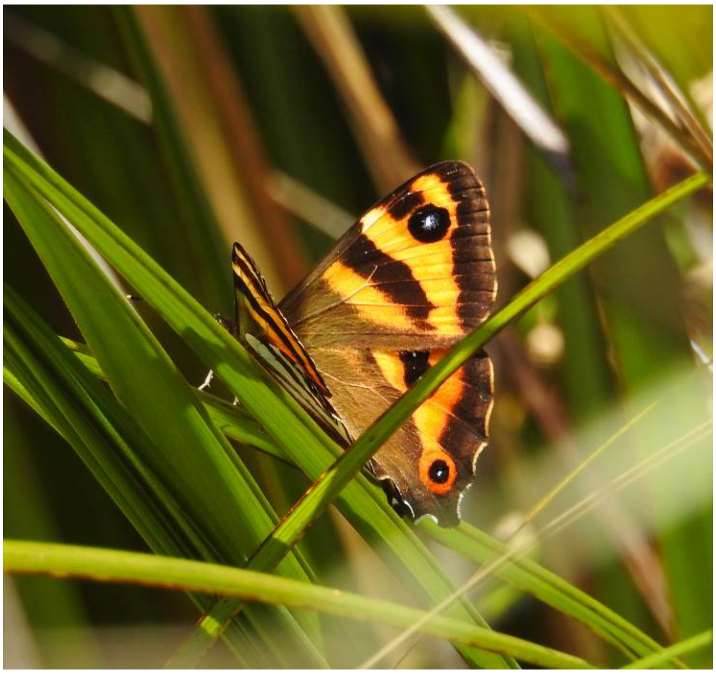
Dodonidia helmsii
Forest Ringlet Butterfly

Review of the Literature, Analysis of Current Data, and Proposals for Future Conservation

S R Wheatley



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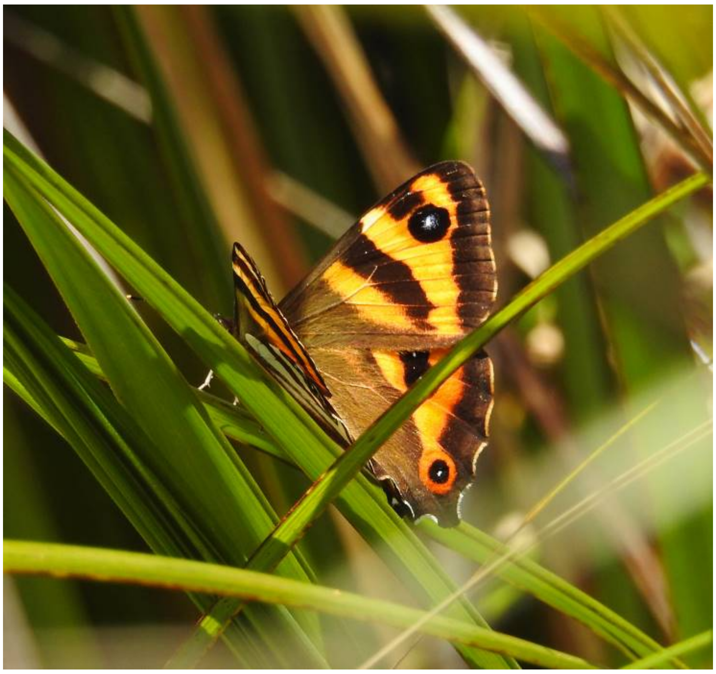


Forest ringlet photographed 5 December 2016 by Sara Smerdon

Introduction

This report summarises the literature and the information related to the forest ringlet butterfly *Dodonidia helmsii*. This is bringing together information from a wide range of sources, including face-to-face discussion and personal observations from the period November 2016 to January 2017. Through review and discussion we can achieve a better understanding of the status and conservation needs of the butterfly. Some objectives for ongoing work are proposed. Specific actions can be derived from this list.

Introduction to the Butterfly

The forest ringlet butterfly *D. helmsii*, also known as Helms' butterfly, is a butterfly of the family Nymphalidae, and endemic to New Zealand. It is the only species in the genus *Dodonidia*. Tillyard (1926) suggests it is a relative of the *Oriexenica* genus, found in Australia.

As early as 1896 Marshall referred to the "great rarity of the butterfly". Tillyard (1926) described the forest ringlet being "in a few localities in both islands" and "a rather rare, local species, widespread in the forested areas", while Gaskin (1966) said "it seems to be local rather than rare". It is certainly true to say that it is rarely seen. Maddison estimates that perhaps less than 100 people have seen and identified the butterfly in the wild (*pers comm.*, November 2016).

Both Gibbs (1980) and Hoare (*pers. comm.* December 2016) describe the butterfly as "probably the most beautiful of New Zealand's butterflies", and it was described by New Zealand Post, during their 1991 printing of a collection of butterfly-themed stamps, as "the most vividly coloured of all New Zealand butterflies" (New Zealand Post website)

The butterfly has also been called the silver streak and beech forest butterfly. For the purposes of this report the butterfly is referred to as the forest ringlet or by the most commonly accepted scientific name *Dodonidia helmsii*.

Photos of all stages are available at http://nzbutterfly.info/resident/forest-ringlet and in Gibbs 1980.

Background and Status

The forest ringlet is classified by the Department of Conservation (DOC) as At Risk: Relict (Stringer et al. 2012). In 2004 the status had been changed from Gradual Decline to Serious Decline "as a precautionary approach". Wasps (Vespulidae) were mentioned as predators.

The suggestion is that the butterfly has suffered a decline in both abundance and distribution. A widely held belief is that the butterfly has disappeared from lowland sites, despite there being plentiful habitat, and suggestion that only small, remnant populations remain at high altitudes.

Patrick & Patrick (2012) point to a reduction in range over last 30 years, when previously it was widespread and locally common, stating that less than 20 populations are known (Wildlands report, 2014).

This loss is said to have occurred particularly at lower altitudinal range and close to urban areas (Patrick & Patrick 2012 and nzbutterflies.info website, Dec 2016). It has been feared the butterfly has disappeared completely from the Waitakere Ranges (west of Auckland, 474m, last confirmed record 1996) and the Hunua Ranges (east of Auckland, 688m, last confirmed record 1990). Hansford (2009) reported that forest ringlets have disappeared from forest below 400 m (ref…. Hansford, Dave (Jan–Feb 2009). "Ghosts of Summer". New Zealand Geographic (95)). Patrick & Patrick (2012) suggest it is now confined in some areas to altitudes above 700 m.

Crowe (2002) says the butterfly was once widespread in New Zealand, including the Wellington and Auckland area, but has become significantly rarer over the last 50 years. This situation seems to have been confirmed by larval searches undertaken in the hills above Eastbourne on the eastern side of the Wellington Harbour, where annual larval counts have dropped from an average 19+ in 2001 to less than 1 in 2014-15 (from Gibbs' notes).

Notably the DOC conclusion on the status of the butterfly recommends a concerted survey effort to give confidence and confirmation of status.

Edwards (*pers. comm.*, 2017) has suggested the conservation community seek to develop 'icon' species status in New Zealand for the forest ringlet butterfly. This is because:

a. it can be an insect emblem to match kiwi, kaka, kauri and cabbage tree, and,

b. it is equally rare to see and can be conserved, recovered with the same objective to return to urban environments as native birdlife and plant life,

c. it is also associated with forest,

d. being a beautiful, distinctive butterfly, it may be considered more attractive than other NZ conservation such as weta.

Extinction Concern

The nzbutterfly.info website states (Dec 2016) the forest ringlet is probably the most likely butterfly to become extinct. Gibbs said he fears the butterfly is sliding towards extinction (*pers. comm.* Dec 2016). Despite this, there are continuing but sporadic sightings of the butterfly and the suggestion that the butterfly is still fairly common and widespread at higher altitude, particularly at South Island sites (Patrick *pers. comm.*).

Abundance Change

There are both historical and recent accounts of the butterfly occurring in abundance. One report (in Craw 1976) mentions 20-30 individuals seen in one hour at Coads Creek, Dun Mountain. Another report (from D W White, also in Craw 1976) mentions fifty plus individuals of *D. helmsii* observed on each of two days (12 and 19 December 1970) in the Waitakere Ranges, near Auckland.

There have been some recent relatively high counts also; Patrick recorded a count of 26 at a South Island site in 2008, and Twigge counted 29 at a North Island site in 2011. Therefore, with the exception of the Eastbourne site monitored by Gibbs, there is possibly not evidence of a general decline in abundance. However, as Millar & Patrick (2016) point out, any stability of the population is an assumption based upon a lack of documented evidence to the contrary

The Forest Ringlet Project

The Forest Ringlet Project was established in November 2016 by the Moths and Butterflies of New Zealand Trust. The project is expected to run for five years and the goals are:

1. To gain vital information towards evaluating the viability of a restoration project for this butterfly
2. To set up a foundation colony
3. To get comparative material for DNA studies of the population variation in the forest ringlet.
4. To assess what parasites and predators are present in the environment of the host plants.

Forest Ringlet Records

At the time of writing the Forest Ringlet Project has collated and compiled 265 *D. helmsii* records of varying completeness and from a variety of sources. These records account for at least 715 individual forest ringlets. Where site names are included, a grid reference has been derived, either through contact knowledge, contact with the recorder or via a New Zealand Gazetteer of place names which provides an approximate and imprecise location of sightings. These records provide useful insights but the dataset is probably too small to allow valid statistical analysis. Much more data would be very useful and would be required to allow for statistically significant analysis.

No confirmed records could be found for the vast eastern (Gisborne and Te Urewera) area of the North Island. Barker (in 2012) compiled accounts of forest ringlets in this area 1950-1979 but details could not be found for this report. *Gahnia pauciflora*, *G. procera* and *G. setifolia* and *Chionochloa conspicua* are recorded in this area (GBIF).

Habitat

Hudson (1898) references *Gahnia setifolia*, "…which always grows abundantly in the birch forests where the butterflies are found". The forest ringlet is often associated with beech forest (*Nothofagus* sp.) (e.g. Crowe 2002) and also mixed beech/kamahi *Weinmannia racemosa*, but Gibbs (1980) notes it is not restricted to these forest types and the different habitats might not be directly comparable. Localised distribution appears to be defined more appropriately by the structure of the vegetation (edges of glades/clearings and in light pools created by tree fall) which can provide a favourable micro-climate and niches for foodplants, especially *Gahnia*, primarily on granite soils and under taller vegetation and on *Chionochloa* sp. which might be increasingly prevalent further south. Presence (and ideally an abundance) of nectar plants is likely to be the other key factor.

There are suggestions the forest ringlet is far from being a purely forest butterfly; Marshall (1896) describes the butterfly at Wanganui in well-defined swamp with a Hebe, *Veronica salicifolia* now and then. He described "all specimens were captured in small bush-gullies, the sides of which are partially cleared of the light bush that formerly covered them". David Riddell (Naturewatch website) describes seeing the butterfly in a very open area with widely scattered canopy trees, looking like it has been partially cleared, or maybe had a big fire or storm go through it some decades ago. Ian Millar and Patrick noted butterflies on sparse ground at a narrow string of low manuka over dense *Gahnia* in a small, relatively shallow gulley (Wildlands report, 2014).

Habitat descriptions by Marshall (1896), Millar and Patrick (2014) and Riddell (Naturewatch website) describe areas that had been cleared or modified in some way. It might be the case that the butterfly is able to make use of the more open habitats which are either relatively static (as with tussocks above the treeline), or in a state of re-vegetating transition back towards (but not yet at) more natural, high-canopy cover.

[But could it be that the butterfly is easier to see in such sites – Ed.]

Millar and Patrick (2016) found that larvae were abundant on the host plant *G. procera* in the understorey of the shrubland and low forest areas of the Te Kuha Mine site, with Patrick stating that the population here is the largest known to him (*pers. comm.*).

Ovum

Eggs are laid singly on the under-surface of leaf blades of food plants, approx. 1 mm from the edge (Gibbs).

Being light coloured/very pale and relatively large (1.4 mm) the eggs stand out surprisingly clearly (Gibbs, 1980 and *pers. comm.*). The eggs are said to darken to yellow-green after a few days. The ovum is spherical with about 50 fine vertical ribs, which appear towards the upper half, the bottom part being smooth or pitted. The adhesive is also usually visible.

Patrick & Patrick (2012) say females prefer to lay eggs on shaded plants and this might be borne out by observations of plants with apparent larval feeding damage. Eggs hatch after about 22 days (Gibbs 1980). Three days before hatching, the shell becomes transparent, letting you see the eyes and jaws of the developing larva. The next day the whole head darkens the upper part of the ovum.

Photo: Michael Reid

Forest Ringlet as Specialist

This precise strategy of laying eggs singly on the larval foodplant is indicative of the forest ringlet being a specialist species of butterfly rather than a generalist. The butterfly might also lay relatively few eggs; examination of a caught female by Twigge revealed it was carrying only 20 or so eggs (*pers. comm.*) although it is unknown how many eggs had already been laid and how many more it could produce.

Specialist species are generally more sensitive to environmental change (see Erhardt & Thomas 1991). Change might be represented in habitat or other pressure such as the arrival of new predators, as might be a particularly relevant issue in New Zealand. In terms of habitat change, Schäpers et al. (2016) reports that species with more discriminating females had larvae that were less able to deal with a suboptimal initial feeding site compared with relatively indiscriminate females of which the larvae are better able to cope with suboptimal sites.

Despite this precise/maternal behaviour there does seem to be a variety of related sedges on which the butterfly will lay; *Gahnia* (sometimes described as forest sedges) *G. setifolia* (D'Abrera 1977; Hudson 1898)*, G. procera* (Gibbs 1980)*,* cutting sedge *G. pauciflora* (Gibbs 1980) and *Chionochloa* species -– *C*. *flavicans,* narrow-leaved bush tussock *C. cheesemanii* (Gibbs 1980), snow grass/hunangamoho *C. conspicua* (Gibbs 1980, Patrick & Patrick 2012, Twigge *pers. obs.*).

Gibbs (1980) notes that young leaves are preferred. He also noted eggs laid on *C. cheesemanii* (primarily in the South Island) which has particularly narrow leaves, meaning the relatively large egg is wider than the leaf and can be very conspicuous.

Ecology - Larvae

Newly hatched larvae are 5 mm long, stout with a conspicuous black head capsule. The shell is eaten by the newly hatched larva but the larva may not start feeding on leaf material for three days (from Gibbs 1980 – images of the larvae are included in this book).

At second instar the head and tail grow bifid projections and the black head is discarded. The larvae have lines on the sides and top of the body that are darker and lighter than the body (description from nzbutterfly.info). The larvae grow to about an inch and a quarter [3.2 cm] (Gaskin 1966) and are markedly pointed at both ends.

The larvae feed largely at night and rest near the feeding place on the underside of a leaf of the foodplant by day (from Hoare notes, December 2016). Gibbs (1980) found the favoured foodplant on the North Island appeared to be *Gahnia pauciflora*, which is commonly in beech forests although this might not be the dominant foodplant available; Gibbs reports the dominant foodplant available at Mt Ruapehu, Gouland Downs and Kahurangi National Park is *G. procera*. My own survey of Kahurangi National Park supported this assessment (*pers obs.* 2016) and is supported by suggested distributions of the different *Gahnia* spp. within the Global Biodiversity Information Facility (gbif.org).

There is some uncertainty around *Chionochloa flavicans*; Ramsay (1980) noted occasional notched *C. flavicans* leaves near several species of *Gahnia*, and once noted a green caterpillar (not identified in the source). Gibbs has not heard of *C. flavicans* being used (*pers. comm.*) and believes possibly these notches were created by a noctuid – maybe *Graphania infensa*, as this caterpillar is also green, or some other species. However, Dugdale reared larvae (last or penultimate instar) on *G. setifolia* and tillers of *C. conspicua* or *C. flavicans* and feeding seemed to take place on both equally (correspondence from Dugdale to Gibbs, 1976).

Photo: Michael Reid

I have found no reference suggesting the butterfly uses *G. xanthocarpa*. A survey of *G. xanthocarpa* in the Waitakere Ranges, west of Auckland (January 2017) revealed no feeding damage of any kind on these leaves.

[But forest ringlet has apparently been lost from Waitakere – Ed.]

This *Gahnia* is abundant and widespread within the Waitakere Ranges, often within areas where the habitat structure appears to be very favourable. One must assume that the butterfly cannot utilise this foodplant, otherwise there must certainly be some other agent preventing the butterfly from flourishing here.

Simpson and I also noted occasional but very similar feeding damage on adjacent *Carex* species (possibly *C. geminata*/rautahi) (*pers. obs.* December 2016) and found a green larvae ([yet to be identified, but not *Dodonidia*]). The website nzbutterfly.info also mentions larvae on *C. geminata* (original source unknown).

Twigge (*pers. comm.*) observed a captive larval preference for *G. setifolia* over *G. procera* (Twigge, *pers. comm.*). The captive larvae were put onto *G. procera* but moved repeatedly to adjacent *G. setifolia*. However, this cannot be guaranteed to be a reliable indication of wild behaviour as the behaviour of captive stock can potentially be different to caterpillars in the field. There certainly appears to be feeding selection preference hierachy for where more than one species of *Gahnia* occurs, although we cannot ascribe all of this evidence exclusively to the butterfly. Roger and Sarah Frost have found notching on *G. rigida* close to their own home near Murchison, but they have not observed the butterfly there.

Frost (*pers. comm.*) inspected an area of where *G. procera* and *G. rigida* occur but found notching only on the *G. procera*. Roger did find notching on *G. rigida* but only where this was the only *Gahnia* species present.

Tillyard (1926) reported a larva feeding on *Uncinia*. However, no more details were given and there are 30 species of *Uncinia* endemic to New Zealand according to Moore & Edgar (1970). This is the only forest ringlet reference to this foodplant that I have found and there are known to be certain Noctuids such as *Graphania infensa* (Dugdale *pers. comm.* January 2017) that feed on *Uncinia*, and therefore there may be some questions as to the validity and/or relevance of this observation.

[NOTE – Recent revision transfers *Uncinia* species to the genus *Carex* – Ed.]

It seems that there are a number of foodplants (*Gahnia* and *Chionochloa*) which the butterfly uses. Dugdale (in Gibbs, 1980) comments that this apparent variety and choice of sedges and forest tussocks is an 'elegant' survival strategy, offering a wider range of forest types.

The NZ Plant Conservation Network species factsheets (downloadable from www.nzpcn.org.nz) are very accessible and useful for identifying the different *Gahnia* and *Chionochloa* species.

Larval behaviour

The night-time feeding behaviour of the larvae produces a distinctive notch in the leaf (photo also available on nzbutterfly.info) which elongates further as the larva feeds over a number of days, ultimately leaving just a thin strand of leaf remaining above the initial feeding point (Patrick *pers comm.*).

Examples of feeding damage found on *Gahnia* (photos: Steve Wheatley, December 2016)

Larvae feed mainly (though not exclusively) at night, and rest near the feeding place on the underside of a leaf of the foodplant by day, head-down about 30 mm below the notch they are presently eating (various sources, including Gibbs 1980). The larvae can spend several days on a particular leaf (from Hoare notes, December 2016 and nzbutterflies.info). Frost (*pers. comm.*) recorded a single caterpillar feeding at 3:30pm having earlier in the day seen it rest 300 mm from the feeding notch. There is some suggestion (source unknown) that parasitised caterpillars might be more likely to feed during daylight hours.

The larvae itself is well camouflaged being a similar colour to the leaf. It is far easier to find the indicative feeding damage than finding the larvae itself.

The larvae expel a straw-coloured frass (Twigge *pers. comm.*) which drops from the foodplant. Simpson and I also found frass matching this description on the foodplant adjacent to feeding damage (*pers. obs.* December 2016).

Gibbs (1980) details the larval stages in detail. The larvae live for approximately ten months and go through five instars; after about 30 days the first moult occurs and the black head is discarded in favour of a forked green head. Larvae reach second or third instar before winter forces them to cease feeding in May, at which point they seem to disappear from the foodplant. It is surmised that the larvae overwinter (in hibernation or diapause) at the base of the foodplant or nearby. Little is known about the overwintering strategy of the larvae, although Twigge has observed captive larvae burrowing into loose soil (*pers. comm.*). Other sources mention the larvae 'leaving' the host plant (source unknown), although it is unlikely and counter-intuitive that they would move too far away from the foodplant.

A better understanding of the overwintering strategy would be useful as this can be time when invertebrates can be particularly vulnerable to predation and other forms of loss.

Looking down into the centre/base of a large *Gahnia procera* – a potential overwintering location?
(photo: Steve Wheatley, December 2016)

Feeding resumes in September/October. Gibbs (1980) suggests larvae are fully grown (34 mm) by mid/late December, although this might relate to specific observations in the Wellington area.

<u>Feeding Damage Surveys</u>

The feeding damage that occurs is distinctive and easy to find but is not diagnostic. Several noctuids, including *Graphania infensa* and *Tmetolophota* spp. also feed on sedges and produce a similar feeding pattern, although these specific noctuids tend to prefer *Uncinia* and *Carex* respectively (Dugdale *pers. comm.* January 2017).

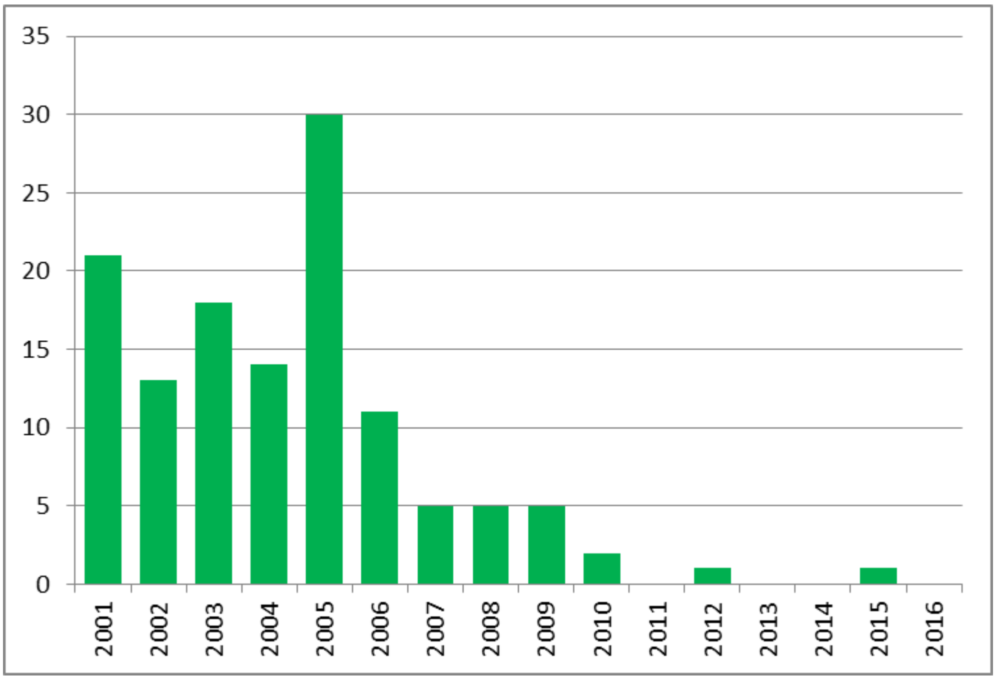
It would be very useful to gather information about other species utilising the same host plants and in particular their seasonality, so that visits to potential sites can be timed appropriately to try to determine which species are making the feeding notches.

Frost has also experimented with ‘aging’ the notches, finding that the edges show the distinctive browning after about ten days (Frost, *pers. comm.* 2017). This suggests that notches that do not exhibit this ‘browning’ of the edges are likely to be less than ten days old.

Larval Searches and Surveys

There are many records of larvae being found in the wild; 11% of the *D. helmsii* records collated by the Forest Ringlet Project relate to larvae (to 8 January 2017). Twigge (*pers. obs.*) often undertakes a methodical blade-by-blade search of the foodplant exhibiting feeding damage. This can take up to half an hour per plant. In a three-hour visit to a site where *D. helmsii* have been regularly and reliably recorded (including the high count of 29) Twigge found two larvae (7 January 2017).

Since 2001 Gibbs has undertaken a structured and repeatable survey of foodplants in the hills above Eastbourne, east of Wellington. This is carried out by beating the plant over a beating tray of contrasting colour to the green caterpillar (he has previously employed red or purple umbrellas). By visiting the same plants and recording the results over a fifteen-year period (2001 to present) Gibbs has recorded the dramatic and worrying decline in larvae occurrence, as detailed earlier.



Larval count at Eastbourne by George Gibbs 2001 to 2016.

Both these methods obviously have the potential to confirm presence and confirm foodplant use.

Gibbs’ method provides possibly the most efficient and applicable, standardised and repeatable method of survey. This also has the potential to generate useful survey records and long-term data for other species and taxa. This method also has the potential to generate a useful index by which other factors might be compared.

Ephemeral Populations

In addition to the low population density and natural elusiveness of *D. helmsii*, there are many observations which suggest local populations might be ephemeral in nature (Twigge *pers. comm.*;

Arter Williamson *pers. comm.*). It is suggested that the butterfly can potentially disappear from some localised sites and 'appear' at other sites.

Following a sighting of the butterfly near Wanganui, Marshall (1896) stated "Though I have frequently visited these gullies in previous summers […] I have never previously seen any specimens of this butterfly. Mr Drew, curator, Wanganui Museum, assures me that […] though he has often shot over these gullies, he has never seen any specimen of the butterfly".

The strategy of 'moving' around a landscape as response to parasite numbers and populations is documented in various sources and could be a reason for a perceived change in butterfly numbers at specific sites (e.g. Lindsey et. al. 2009, *Crowding and disease: effects of host density on response to infection in a butterfly–parasite interaction*). Parasitisation of *D. helmsii* is discussed below.

<u>Variations in Larval Stage</u>

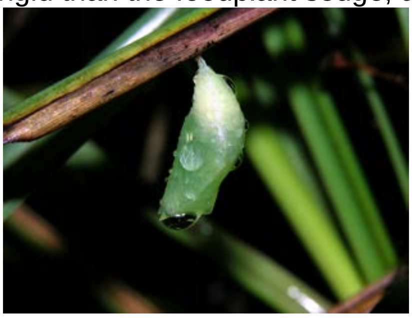
Observations based around Wellington (by Gibbs) confirm the life cycle is likely to take a full year and that this is likely to be the same in other lowland areas. However, Gibbs found two age groups are overwintering, suggesting that the life cycle might be different for different individuals. Gibbs suggests individuals might be taking two years to complete their life cycle. At high altitudes, samples of larvae have also included second to fifth instar larvae in November (Gibbs). Patrick & Patrick (2012) also found two size classes of larvae (10 mm and 26 mm) and took this as confirmation that the life cycle is two years but that some butterflies emerge every year. Helms informed Hudson that he had seen adult butterflies near Greymouth in October, and concluded that there are two broods in the year (Hudson 1898). Ruapehu is another suggested locality where a two-year life cycle might be taking place (Twigge *pers. comm.*).

<u>Pupation</u>

Photos: Michael Reid

Before pupating, the larvae hang upside down by the cremaster in a sheltered location for about three days slowly losing their colour before moulting into the pupa. Pupae are brown/green (a common dimorphism) and stout with white edges and reddish outline on wing cases (photo on nzbutterfly.info website). Gaskin (1966) proclaimed that the pupae were "almost as pretty as the adult".

Hudson (1898) records the pupae suspended by the tail to any firm object in the neighbourhood of the sedge. Gibbs also suggests pupation sites are away from the foodplant, on something more rigid than the foodplant sedge, although Twigge (*pers. comm.*) has also found the pupae suspended on rigid blades of the *Gahnia* itself. Gibbs (1980) recorded pupation lasting about 20 days.



Given this timescale and the assumed flight period of the butterfly (see below), pupation would most likely need to begin by mid-January at the latest, and if the flight season data (below) is correct, the majority of *D. helmsii* individuals would begin pupation in December and some would begin in November or even earlier.

<u>Imago (Adult)</u>

Gaskin (1966) describes the butterfly as “pretty and striking” and I have to agree. It has been described the most vividly coloured of all New Zealand butterflies” (New Zealand Post website), and Gibbs (1980) suggested it is possibly New Zealand’s most beautiful butterfly.

Wingspan is commonly quoted as being 40-64 mm (terrain.net.nz; nzbutterfly.info). Specimens of the butterfly appear to be generally larger from the north; Gibbs notes that local variations in size are noticeable, with specimens from Ruapehu and Wellington averaging 53 mm and specimens from the Waitakere Ranges, Auckland being up to the largest wingspan, 64 mm Patrick & Patrick (2012) suggest the wingspan of southern specimens ranges from 44 mm to 50 mm.

The specimens from Dun Mountain area near Nelson are generally noticeably small and nearer the 44 mm end of the scale. This is thought to be due to a particular mineral belt that also seems to have a specific dwarfing effect on the vegetation and some insects, such as Janita's tussock butterfly, *Argyrophenga janitae* noted in Gibbs 1980).

Comparison of size difference between a North Island specimen (top) and a Dun Mountain specimen (bottom) - from Te Papa Museum collection, photo Steve Wheatley December, 2016

This difference between populations has led Maddison, Patrick and others to wonder if some speciation is taking place. A DNA study could explore any such population variation.

In common with many other species of butterfly, the male typically has a long and slender abdomen while the female has a shorter and stouter abdomen.

Colouration and markings are more constant than other Satyrinae, regardless of locality (Gibbs, 1980).

The Forest Ringlet in Flightj

The forest ringlet flight is described as high, rapid and erratic without gliding (Gibbs 1980; Patrick & Patrick 2012; and *pers obs.*). Patrick observed a similar flight pattern in the *Erycinidia* butterflies of New Guinea forests, which he believes are the *Dodonidia*'s closest relatives.

Gibbs (2012) observed a flight of brief bursts, followed by resting on outstretched sunlit branches for extended periods of time. Marshall (1896) describes the butterfly flapping lazily, alighting on leaves of shrubby trees. In full sun and windless conditions, they keep their wings wide open (sunbathing), but quickly close them if there is any disturbance, even the wind (nzbutterfly.info, from Gibbs 1980).

The forest ringlet generally flies at height, below the tree canopy but above the lower-storey shrubs (from Patrick; Riddell; Gibbs). Shields (in The Weta 41) noted the butterfly 3-4 m above the ground around and above the tops of manuka trees, with a higher canopy of *Nothofagus* present.

At the bush-line at a site on the South Island, Roger and Sarah Frost (*pers. comm.*) witnessed the butterflies emerging in the morning from low vegetation (including tussock and flax), perching for several minutes at a time before eventually moving away around the forest edge and out of sight. They reported that the butterflies were not seen after 11.30 am. Observations such as this would be very useful in understanding the behaviour of the adult butterfly.

Females will generally come nearer to the ground to search for sites to oviposit but return to height if disturbed (Gibbs 1980). Males might also descend in search of females. Shields (in *The Weta* 41) describes how he tried unsuccessfully to catch a ringlet, causing it to rise above the small trees and out of sight. (Shields)

Gibbs (1980, p.77) describes a dependence on sunshine (as is expected of most butterfly activity) and this behaviour of only flying on sunny days is repeated on the nzbutterfly.info website, but there are a few records of the butterfly flying in other weather conditions; Ramsay (1980) describes the butterfly morning-flying and feeding in dull damp misty weather, and Shields (in *The Weta* 41) describes four individuals flying in rain; Twigge (*pers. comm.*) has occasionally recorded individuals flying in overcast conditions.

More diagnostic information about the butterfly in flight would be useful in helping 'forest ringlet novices' to find and positively identify the butterfly. Frost suggests the production of a video. Although this would be difficult to produce it might be possible at a site where the butterfly is well-monitored and relatively accessible, such as Tongariro National Park (with the help of Twigge), or on the Coromandel Peninsula (via Sara Smerdon).

Imago Lifespan

There is some uncertainty as to the lifespan of individual adult butterflies, which has possibly been confused by the various terms – flight period, emergence, lifespan. The generally held view is that the flight period of a local population is less than one month (Gibbs 1980, Hudson 1928, Gaskin 1966, Miller 1971). Crowe (2002) states adults live for 3-4 weeks and this lifespan is also quoted on the nzbutterfly.info website (December 2016), but I wonder if this might be a confusion of *flight period* and *lifespan*, since it is less likely that individual butterflies will live for the entire duration of the flight period. To add to the current confusion Patrick and Patrick (2012) state that *emergence* may be as little as three to four weeks in any one locality.

I have not yet found any clear evidence of the lifespan of individual forest ringlet butterflies (January 2017). This answer is likely to be difficult to resolve, especially since this is a particularly elusive (and potentially highly mobile) species (see discussion below).

Timing of flight period

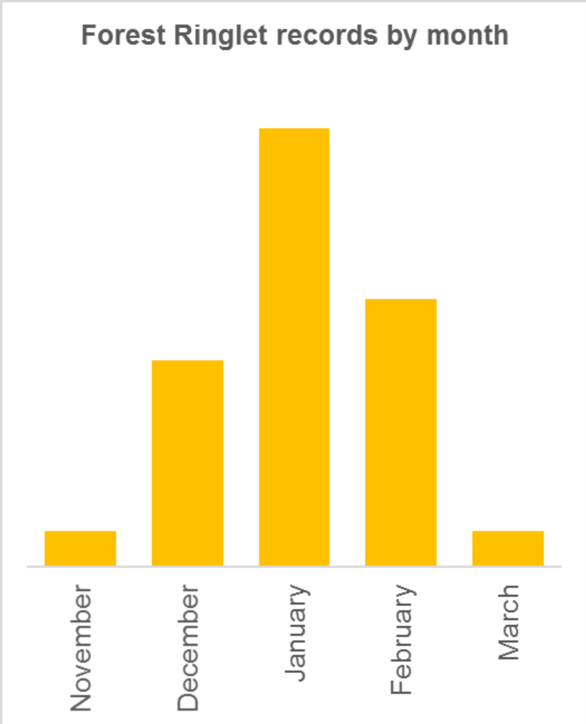
There are many different dates given regarding the flight period.

Records begin as early as late October (Helms in Hudson 1898; also Craw 1976). Despite such early records (discussed separately, regarding the possibility of a two-year life cycle) Hudson (1898) stated that the adult of *D. helmsii* appears in February, but later extended the flight period of the species to January and February (Hudson 1928, from Craw 1976). Hudson (in 1939) also then refined this further to say the butterfly was not found later than the second week in February.

Gaskin (1966) suggested the flight period was usually late January and February (Gaskin, 1966, from Craw 1976) and Miller (1971) stated it limited this period to *only* during January and February (Miller 1971, from Craw 1976). Crowe also suggested the butterfly was found in January and February (Crowe).

Craw himself was more relaxed in these boundaries, suggesting the flight period extends from late December to early March (referring to the Wellington and Nelson areas) (in Craw 1976).

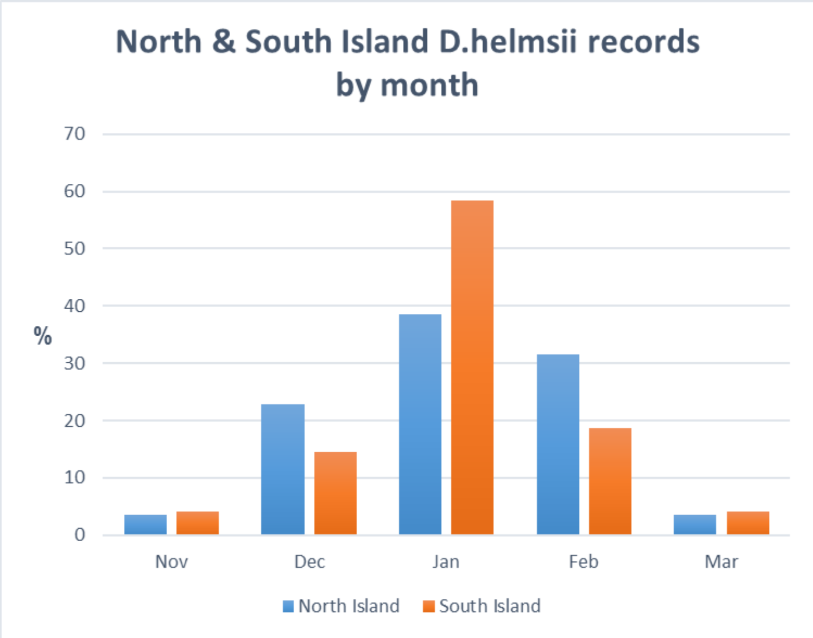
However, the flight period certainly appears to start earlier than reported above (e.g. *pers. obs.* 6 December 2016, Coromandel Peninsula) and historical records gathered from a wide variety of sources (listed in the references), see below.



A summary of 162 recent and historical records of adults collated by the Forest Ringlet Project 2016 (January=72, but notably with 24.9% or records occurring before January)

Note - these pooled records do not suggest the flight period in any one place is November to March; the proposed 3-4 week flight period is likely to occur within this range at different times, in different places.

I agree with Gibbs (1980) that the timing of flight period is likely to vary significantly from year to year and from place to place. Hoare (*pers. comm.*) notes the difference in timings between Auckland and the Wellington district. Given the latitudinal range and altitudinal range of the butterfly these differences can reasonably be expected.



A summary of 162 historical and recent *Dodonidia* records divided by month and island. The total flight periods are similar, suggesting that latitude is maybe less important than other factors.

The table below indicates the likely flight times of forest ringlet, based upon 169 records collated by the Forest Ringlet Project. Each month has four divisions, with each division approximately representing a week. However, flight times are likely to vary depending on locality and seasonal weather, and this table is intended to provide a rough guide only.

	November				December				January				February				March				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
North Island																					(121)
South Island																					(48)

The above summary of 121 North Island records and 48 South Island records, and the bar chart above, suggest the total potential flight periods are potentially equally long but the core of the South Island flight period is likely to be more condensed into a few weeks (predominantly mid-January until early February).

Latitude and altitude are accepted as key factors in the emergence of butterflies and other taxa. Patrick & Patrick (2012) suggest the best time to look for forest ringlets in upland areas is late January.

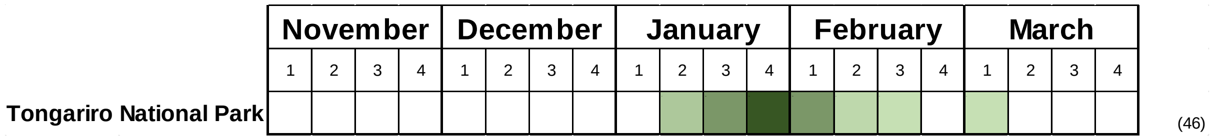
Gibbs (1980) also notes that the flight period can differ and be ‘out of phase’ substantially across a relatively small distance; Gibbs has recorded adults in the Orongorongo Valley from late November to early January) while at Gollans Valley and Eastbourne (only 7 km west) sightings occurred in late January to early March.

A similar disparity in flight season (although over a distance of 90 km) seems to occur in the North, where the butterfly recorded in early to mid-December on the Coromandel Peninsula (*pers. obs.* and Steer *pers. comm.*), but flying mid-January to early February on Great Barrier Island and Little Barrier Island (Lyn Wade *pers. comm.* 2017).

Other likely factors which will influence emergence include annual variations in seasonality (butterflies exhibit a plastic response to temperature, with adult emergence dates earlier in warmer years, see Roy et al 2015) and local micro-climate situations. However, the difference recorded by Gibbs in the Wellington area is quite striking and a further study of such differences might bear new insights into the specific of the butterfly.

There is evidence of some consistency to emergence times, with Gibbs noting no evidence of early emergence east of Wellington Harbour.

Similar analysis of the Tongariro National Park records of forest ringlet identifies a peak flight period of the last two weeks in January and the first week in February. This analysis is possible because there are sufficient records available (46 included here), predominantly from the Ruapehu area.



More data is required to enable more detailed and similar analysis as above of different sites/locales. This information can then provide useful indicators of the timing of emergence and the local conditions. A clearer understanding of local emergence times would substantially help recorders (scientists, enthusiasts and volunteers) to more effectively schedule survey effort, especially as many sites can be in particularly remote locations.

It could be that timing of emergence is synchronised in some way with the flowering of local nectar plants (see ‘flowering and nectaring’ section). Twigge (*pers. comm.*) mentioned that cicadas (*Amphipsalta* sp.) are very loud during his *D. helmsii* surveys at Mt Ruapehu, and I wonder if there is a similar correlation at other localities that could then help identify the best times to look for adult butterflies. Gibbs notes “more careful records need to be made before we can interpret the tantalising pieces of information”.

At the beech forest treeline (especially on the South Island) the range of nectar species among the trees is much reduced. Therefore the flowering season of this reduced range of species could be more strongly related to the butterfly flight season. Frost (*pers. comm.*) questions whether there is evidence of the butterfly utilising alpine flowers at this range. I have not found any reports to support this.

Flowering and Nectaring

The butterfly has been observed and photographed nectaring on a variety of tree/shrub species.


Forest ringlet nectaring on marble leaf *Carpodetus serratus*,
December 2016, photo: Sara Smerdon

These nectar plants are listed in no particular order.

Kamahi *Weinmannia racemosa* is reported to be a favoured nectar plant (Gibbs 1980). This can flower through late spring, summer and autumn (Salmon 1981), providing good options for a varied forest ringlet emergence and flight period.

Manuka *Leptospermum scoparium* flowers October to April (Salmon 1981) and kanuka *Kunzea* spp. flowers October to February (New Zealand Plant Conservation Network website).

Hīnau *Elaeocarpus dentatus* flowers through the spring and summer (Salmon 1981, TERRAIN, NZPCN).

Hebe spp. (such as *Veronica salicifolia*) could be a valuable later summer flower (Salmon 1981).

Putaputaweta/marble leaf/*Carpodetus serratus* can flower throughout the observed flight period – November to March (TERRAIN).

Mahoe/whiteywood/*Melicytus ramiflorus* flowers early in the season and is often predominant on partially cleared land (Salmon). The butterfly has been observed nectaring on this in Coromandel (Allan Rackham, *pers. comm.* Dec 2016).

Kōtukutuku *Fuchsia excorticata* is mentioned as a nectar plant in Marshall (1896) and is common in New Zealand, especially second-growth areas (Salmon). The butterfly was observed alighting on leaves of shrubby trees on fringes of damp woodland that also included use of rangiora/bushman's friend/*Brachyglottis repanda*.

Ramsay (1980) observed the butterfly nectaring on white rata/*Metrosideros perforata* flowers in a southwest Auckland garden on the edge of the Waitakere Ranges.

Maddison (*pers. comm.*) has observed the butterfly on bush lawyer (*Rubus*) flowers at Ruapehu.

Parasitism

D. helmsii is reported to be extremely susceptible to the attacks of a Dipterous parasite.

The larvae are parasitised by a tachinid fly (*Pales* sp.), which lays eggs on the foodplant that are then eaten by a *Dodonidia* larva. The first sign of infection is towards the end of the final instar when a brown spiracle becomes visible on the thorax or eighth abdominal segment of the larva. The parasite will then emerge after consuming the larva in the days before pupation to pupate itself. (from Gibbs, 1980 and nzbutterfly.info).

Gibbs (1980) estimates the tachinid is probably widely distributed.

Out of thirty larvae kept by Hawthorne and Hudson, 75% were parasitised ([source unknown, possibly Gibbs]). Gibbs (1980) recorded a 70-80% level of tachinid fly parasitism of *Dodonidia* larvae on the eastern side of Wellington Harbour.

Gibbs (1980) also documents a case of a tiny wasp (identified by Dugdale as being in the *Trichogramma* genus and different from the tachinid found in the mountains) parasitising an egg of the forest ringlet. The ovum changed colour, becoming jet black. The imago wasp emerged from the shell of the ovum a few weeks later. These parasites predominantly attack tortricid and other noctuid eggs (from Dugdale and Gibbs).

Tachinids have been seen (*pers. obs.*) on *Gahnia* stems at a number of sites where feeding notches are present. In many cases the fly appears reluctant to move from the plant. It might be beneficial to collect some specimens for identification, and this will be especially useful to identify any non-native species that might now be involved. Notably, certain Trichogrammatids have been introduced or tested for biocontrol of certain pest noctuids and have also been introduced as part of the programme to eradicate the large white butterfly, *Pieris brassicae,* in New Zealand.

It is reasonable to expect annual differences in the intensity of larval parasitism (by the tachinid fly) will affect local abundance but there should presumably be some sort of regulatory mechanisms that will ensure the survival of the host and continuation of this parasitic relationship. However, it may be that the predator-prey relationship with the native parasitic fly (*Pales* sp.) or the arrival of a new parasitising species has changed this balance to the point where the parasite is contributing to local butterfly decline. General and species-specific parasite-butterfly relationships are well documented (e.g. Hatcher & Dunn 2011, Lindsey et. al. 2009, Lozan et.al. 2008). However, there is currently no evidence for this specifically being a direct factor in a long-term population decline of *D. helmsii*. Further research is needed here.

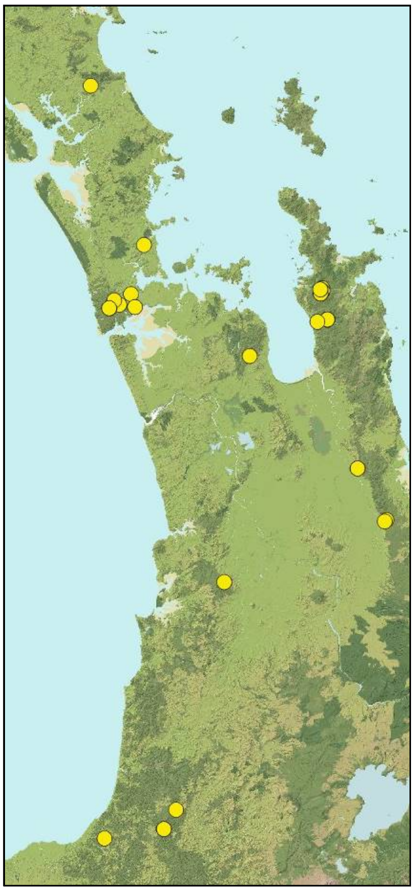
<u>Human Arrival</u>

People of the Polynesian region are thought to have settled the islands later named New Zealand sometime in the late 13th Century. Europeans arrived and began to colonise in the late 18th Century. In these relatively short timeframes the islands and their flora and fauna have been massively altered.

<u>Habitat Loss</u>

Before the arrival of humans, an estimated 80% of the land was covered in forest whereas forest now occupies in the region of 23% of the land (figures from Hammond 1997).

An assessment of 142 *Dodonidia* records collected during the early stages of the Forest Ringlet Project 2016-2017 shows a near perfect correlation of forest/bush vegetation and *D. helmsii* distribution. This would suggest that the forest ringlet has been massively affected by the recent loss of habitat, after millennia of sustainable existence.



An example of historical and recent forest ringlet records
showing relation to the New Zealand land cover
(NZ Landcover 100m, 2009; from Koordinates.com)

Aerial imagery and landcover maps (Google Earth, Koordinates.com, January 2017) suggests not only that forest loss has been greatest on the North Island but that the remaining available habitat is now fragmented and discontinuous. The principles of insular 'island' biogeography (MacArthur and Wilson 1967) tell us that fragmentation of habitat will have led to isolation and greater vulnerability of distinct populations, and this effect will be especially acute on the North Island.

The distribution of records (even recent records) and the occurrence of the butterfly in small fragments of secondary habitat in otherwise unfavourable landscapes (Wildlands report 2014) suggest the butterfly is capable of traversing expanses of unfavourable habitat, but we have no evidence as to the effective colonisation range of the butterfly. This might render remote areas of favourable habitat within a fragmented landscape effectively unavailable to the butterfly.

<u>Habitat Change</u>

Based upon the supposition that *D. helmsii* utilises habitat beyond what might be defined as *natural* forest, the history of the extensive clearance of bush, forest and scrub by settlers and the subsequent return/recovery of some areas of vegetation might have produced mid-successional conditions potentially more favourable to the butterfly (with a relative abundance of food and nectar plants), but further succession to a more closed canopy might be leading to a reduction of the food-plants and nectar plants on which the butterfly relies.

Areas which were historically noted as being favourable spots such as Fairy Falls in the Waitakere Ranges, now seem to be rather closed and dark by contrast to known extant sites.

The landscape-scale polarisation between protected bush and intensively managed land might also be exacerbating the long-term problem for this butterfly; we know that the butterfly food plants have been lost and disappeared from many lowland areas due to farming and forestry activity. An increasingly closed canopy forest might be leading to a reduction in the availability of these essential plants from the protected areas.

The areas that remain largely unchanged will be the upper forest edge of the tree line (higher altitude), and this is where the butterfly might still be common and widespread (Patrick & Patrick 2012).

Predation by Wasps

Gibbs (1980) highlights the anecdotal and circumstantial evidence that numbers have suffered as a result of predation of larvae by introduced social wasps (*Vespula* spp. and *Polistes* spp.). The reported, apparent decline of this butterfly has certainly coincided with the increase in abundance of these predators. Predation by non-native wasps is often suggested as the primary agent of decline of the butterfly (e.g. Terrain.co.nz, Steer *pers. comm.* December 2016).

In the South Island and southern North Island, the altitudinal limits of Vespulid wasps are probably related to (and abundance regulated by…) the limits of red and black beech as sources of honeydew. It is suggested the parasitic German and common wasps have an altitudinal limit of 600m (terrain.net.nz, Hansford, 2009) and as a result the butterfly is still found at higher altitudes. Patrick & Patrick (2012) suggest the butterfly appears secure particularly in remote and precipitous upland valleys. Wasps can occur at higher altitudes (e.g. 1100 m on Nelson Lakes National Park, *pers. obs.* 21 December 2016) but it might be the case that they are not nesting at this height and, as a result are far less destructive. Frost (*pers. comm.*) has observed many wasps at the top of the Hope Range from 1100m to 1200m and black beech trees with black fungal trunks suggesting honeydew. Data on the distribution and altitudinal limitations of non-native wasps could be essential to the understanding of the impacts of these species.

However, the introduction of wasps only dates from the post-WWII period and *Polistes chinensis* even more recently (Maddison, *pers. comm.*, January 2017), whilst early accounts of the butterfly already suggested it was uncommon (e.g. Marshall 1896). In addition, I am not aware of direct accounts of wasps predating *Dodonidia* larvae in the wild and any impacts seem, as yet, to be unproven and unquantified. Research should certainly be undertaken to investigate correlations between butterfly abundance and wasp abundance. It would also be useful to monitor butterfly populations in comparable areas where wasp control is undertaken and areas where wasp control is not undertaken.

The Department of Conservation (DOC) has identified wasp lures and produced a methodology for assessing local wasp abundance (Edwards, *pers. comm.* December 2016). The assessment and monitoring of the butterfly is potentially more challenging. However, *D. helmsii* population indices produced by larvae surveys or adult butterfly surveys might shed valuable light when compared with the wasp data.

Other invertebrates, such as shield bugs, are known to predate butterflies (Gibbs, 1980).

Predation by introduced birds

Introduced passerines such as chaffinches, blackbirds are now ubiquitous throughout the range of *D. helmsii*, including forest and scrub to the treeline and higher (*pers. obs.* December 2016 to January 2017). Both chaffinch and blackbird were introduced to New Zealand around the time the first *D. helmsii* butterfly was recorded (chaffinch was ‘liberated 1862, according to Oliver 1955). Both feed on the ground and are known to take caterpillars.

There is also an intriguing account of a blackbird trying (unsuccessfully) to catch an adult forest ringlet in flight at Mt Bruce, Wairarapa (Flux 1984). Collenette (1935) details more notes on avian predation of Lepidoptera.

The impact of introduced passerines on *D. helmsii* is not known and could be investigated further.

Predation by introduced rodents

Both rats and larvae are widespread across New Zealand including in forest, bush and montane tussock areas.

Predation of forest ringlet larvae by rats has been proposed (Maddison *pers. comm.* November 2016). I have not found any published references that might confirm this, although rats are known to predate larvae generally. Rat control is undertaken at many locations across New Zealand. An assessment of rat abundance and diet might help to identify whether a causal relationship exists.

Mice are another potential, non-native predator of the larvae. Flux (*pers. comm.* January 2017) agrees they could be an agent of decline. Mouse stomach contents analysis in the Orongorongo Valley identified Lepidoptera larvae as the most common food, but ringlets are so uncommon that any occurrence record would be pure chance. Mouse diet is reviewed in King (2005). I wonder if the larvae could potentially be most vulnerable during the winter diapause, which if it occurs within the dense tussocks of the foodplant. These dense tussocks would feasibly be utilised by mice and at a time when mouse food resource is otherwise scarce. However, Hoare (*pers. comm.* 10 January 2017) has seen no evidence of a decline in the noctuid (*Tmetolophota spp.*) using the same foodplant; it continues to be abundant in areas such as the Waitakere Ranges where the forest ringlet appears to have declined or disappeared. We would assume that the noctuid would be equally vulnerable to a potential predator or other agent of decline.

[This would depend on the larval behaviour -Ed.]

Mouse control is not undertaken at the scale of rat control and there are indications of a direct population-size interaction between rats and mice (Flux *pers. comm.*), such that reduction of the rat population might be enabling (through resource availability and relaxation of direct predation of mice by rats) increases in the mouse population.

Further assessment and monitoring of abundance, combined with an instigation of diet might be very useful in determining the potential impact of such mammals upon *D. helmsii* and other species. In conjunction, it would be useful to learn more about forest ringlet populations in areas where the rat population is heavily controlled but mice are not.

Impact of Wild Pigs on Foodplant Abundance

There is the potential for wild pigs to root up *Gahnia* (observed by Simpson *pers. comm.* December 2016). However, the continued abundance of foodplant in forest areas suggest this is unlikely to be having an overall negative impact on *Gahnia*, at the levels of the wild pig population. Conversely, it is possible that this rooting activity could have a positive effect on the abundance of foodplants by providing disturbance that promotes propagation and new, young growth. This positive impact has been observed in the woodlands of South East England (*pers. obs.*; Sims 2005).

Butterfly Collecting

The habit of collecting of wild butterfly specimens in New Zealand is widespread (*pers. comm.*, various anonymous sources). The forest ringlet is likely to be of particular interest due to its elusive nature and its perceived scarcity. Even some individuals claiming to be connected to the conservation movement appear to be engaged in (or enabling) collecting (*pers. obs.*, *pers. comm*, anonymous sources). There are reports of individuals taking every butterfly that they could catch from a location on a single day and returning to the same location on subsequent days to collect more. The impact of this collecting on a butterfly which exists at relatively low population density and with a relatively low reproduction rate is very possibly having a seriously negative impact on local populations. Minteer et.al (2014) explains how even responsible specimen collection can indeed magnify and combine with other forms of extinction risk for small populations of rare and vulnerable species.

There are many examples of species collection contributing to the local/national extinction of species, and in line with the tragedy of the commons theory (outlined by Lloyd 1833 and expounded in Hardin 1968), collecting could become more selfish and acute as the resource declines.

The sharing of information regarding the locations and populations of *D. helmsii* may need to be restricted or made confidential in order to protect vulnerable populations. Specific information about sites visited and/or researched by me is not included in this report. The selfish (and in my opinion, disgraceful) behaviour of people willing to take the butterfly from its habitat has a severely limiting impact on the potential to develop public engagement and involvement in the conservation of the species. Any/all data must be handled very carefully and kept confidential. It is my opinion that use of Naturewatch NZ and i-Naturalist risk putting forest ringlet populations in greater risk of localised extinction. The culture and behaviour of collecting butterflies and other taxa needs to be addressed at the highest levels.

[It is even more shameful that specimens of forest ringlet have appeared for sale on trading websites – Ed.]

Climate Change

Climate change is affecting the distribution and seasonality of species across the globe as well as contributing to species decline (e.g. see Palmer et al. 2015). The relative extensive and well-connected habitat and the apparent strong dispersal ability of the butterfly should help to ameliorate changing climate and impact of extreme weather events, especially on the South Island. However, in areas of the country where the habitat is more limited and/or fragmented, localised extinctions could be more likely. Protection of existing habitats and restoration of habitats and habitat linkages are likely to become more important in the scenario of climate change.

The changing seasonality could also be impacting the butterfly and its food and nectar plants. This could see flight periods change, thus making it more difficult to survey and monitor the butterfly.

Summary

The forest ringlet appears to exist at low density and in localised populations in/around native bush across New Zealand's North Island and the northern half of the South Island. Historical accounts suggest a similar picture. Broad examination of historical and recent *D. helmsii* data on distribution and abundance does not provide conclusive evidence of a national decline, although this is based on a small dataset which is insufficient to derive strong statistical evidence in either direction.

The butterfly seems to be found in discrete areas where one of the favoured foodplants plus nectar plants and light are abundant (*pers. obs.*). Absence of one of these factors in sufficient abundance might be enough to preclude the habitat for the forest ringlet.

The existing available habitat, although greatly reduced over the last 800 years (especially over the last 150 years), appears to be sufficiently intact, stable in structure, and of a scale to support healthy, dynamic meta-populations. There is only local and circumstantial evidence of decline. Whether this is just a localised factor or evidence of a wider issue cannot be determined from the existing dataset. Much more data and more structured recording is clearly needed. That said, the forest ringlet's low population density, infrequent sightings and potentially ephemeral nature mean the butterfly is challenging to survey and monitor.

The absence of proof does not imply that a serious decline is not taking place within the existing habitat. The agents of any decline are likely to be new and linked to human colonisation; obvious candidates are new/introduced species such as wasps and/or rodents. Ongoing control and monitoring of these groups will be essential and beneficial for a wide suite of New Zealand's native flora and fauna, regardless of any direct causal link between these groups and the butterfly.

Ongoing habitat destruction and butterfly collecting are activities which are going to lead to localised extinctions. Without change, this will ultimately lead to the complete extinction of this part of New Zealand's (and the world's) unique heritage.

[NOTE - The author declined to comment on whether there is a need for propagation of the forest ringlet to help in the conservations efforts for this species. However the Moths and Butterflies Trust of New Zealand believe there is merit in building captive colonies for the purposes of:

1. understanding more of the life-cycle and biology of the forest ringlet.
2. establishing the methodology for rearing the butterfly in captivity.
3. promoting the understanding of this special New Zealand butterfly both for its potential in future conservation work and in educational work.

Peter Maddison (April 2017) (ed.)]

Recommendations

- The New Zealand conservation community should push for greater conservation recognition (including 'icon' status) of the forest ringlet.
- Formation of a respected authoritative science advisory group, plus support for the MBNZT to guide the activities managing, researching, promoting and funding ongoing conservation and public engagement efforts.
- Advocating for strong protection and dramatic restoration of existing native bush habitats, including the control/removal of non-native/invasive species.
- Restoration of native bush flora, connectivity and buffers especially on the North Island.
- Promote and foster various elements of a research programme that leads to a better understanding of the status of the butterfly, changes in distribution and abundance (at a local and a national level), and identifies any agents of the butterfly's decline, to include:
    a. advocating for ongoing control and monitoring of potentially invasive non-native species, including wasps and rodents. Looking for causal relationships between predators, parasites and *D. helmsii*.
    b. development and roll-out of a structured *D. helmsii* monitoring programme.
    c. significantly increased data collection on the range and distribution of *D. helmsii*.
    d. undertaking forest and habitat research in bush locations to better understand the specific habitat structure, utilisation and resource requirements of the butterfly.

e. identification of areas where the conservation of *D. helmsii* should be afforded high priority.

[Note : The following recommendation is added by the Moths and Butterflies Trust of New Zealand:

f. investigating captive rearing of the forest ringlet as a means of further understanding the biology and conservation requirements of this species, and as having value for promotional and educational purposes towards the conservation efforts. {ED.}]

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Peter Maddison *pers. comm.*
Robert Hoare *pers comm.*
Te Weta

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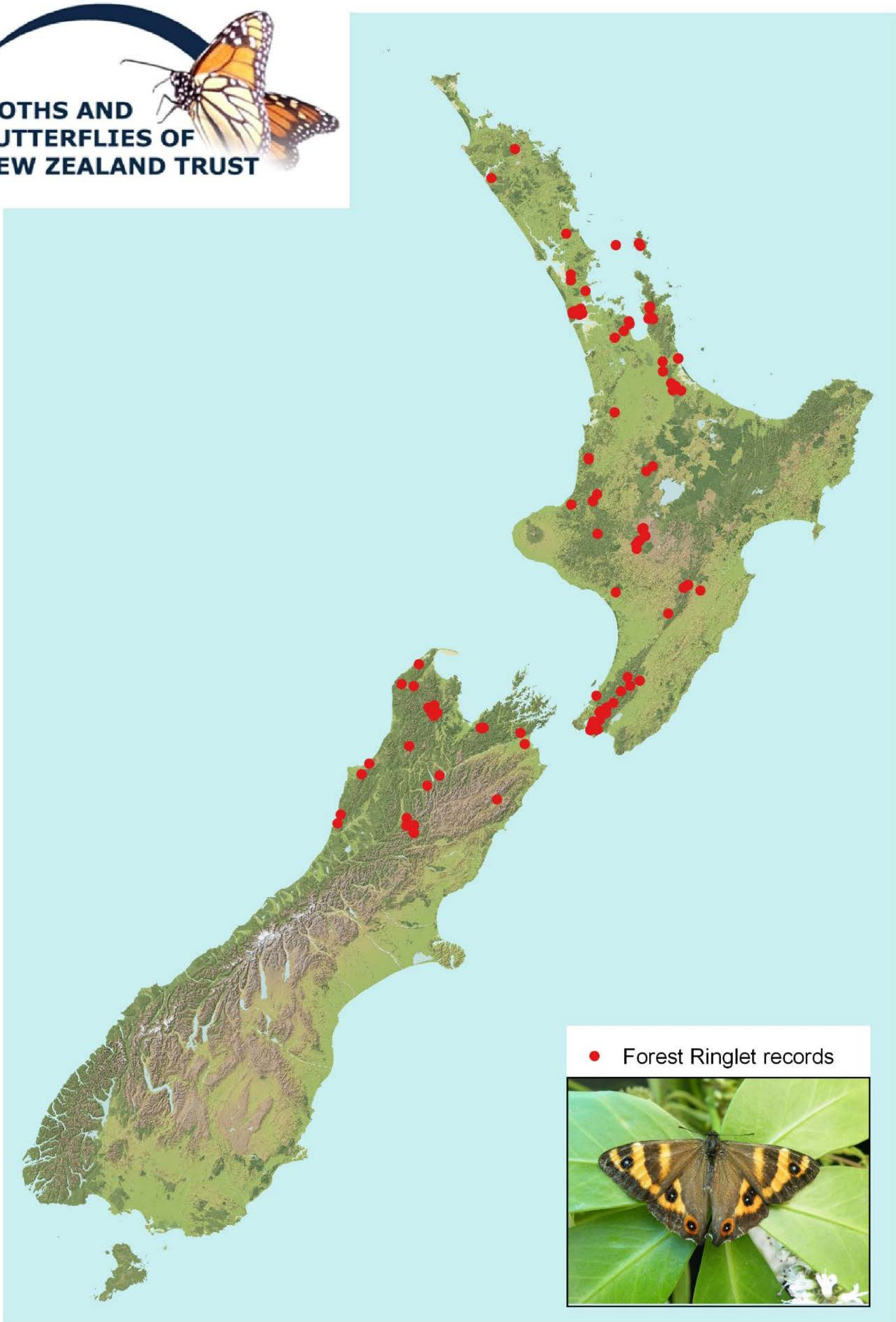

Mapping of historical and recent *D. helmsii* records collated by the Forest Ringlet Project (25/03/2017)

NOTES

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