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COMPARATIVE STUDIES ON THE IMMATURE STAGES AND BIOLOGY OF *HESPERIA COLORADO IDAHO* AND *HESPERIA JUBA* (HESPERIIDAE)

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ABSTRACT. Comparative illustrations and notes on morphology and biology are provided on the immature stages of *Hesperia juba* and *Hesperia colorado idaho* (Hesperiidae) in the Pacific Northwest. Overwintering is demonstrated to occur as either eggs or first/second instar larvae in *H. juba*, and the presence of final instar dormancy/aestivation in summer larvae of both species is reported for the first time in *Hesperia*. High quality images of all stages including larval instars are provided and differences between the species highlighted. As larvae matured, *H. juba* was generally darker colored than *H. colorado idaho* and retained a black head capsule throughout development. The head capsule of mature *H. colorado idaho* larvae was characterized by broad pale areas. *Hesperia juba* overwintered as first or second instars when eggs were laid in September or as fully formed embryonic larvae in unhatched eggs laid in October. Post-winter larval development was rapid, developing from second instar to adult in 7 weeks at 15–22°C. Development of the spring larval generation was rapid until early-mid July when fifth instars entered a non-feeding aestival dormancy, delaying pupation until late August. *Hesperia c. idaho* mostly overwintered as eggs containing fully formed embryonic larvae; however, a small number of eggs from one cohort hatched during August–September into dormant, yellow-orange, non-feeding first instars that overwintered. The majority (~95%) of overwintered eggs exposed to 25 ± 0.5° C and continuous illumination did not hatch but remained viable. Eggs that did hatch produced larvae that developed rapidly at 25 ± 0.5° C reaching fifth instar after 36–39 days. Fifth (or sixth) instar larvae entered a non-feeding dormancy extending this instar to 27–46 days. Final instar larvae of both species produced a flocculent secretion from two pairs of ventral glands between segments 7 and 9, which was incorporated into the pupal shelter and is presumed to function as a moisture repellent.

Additional key words: overwintering, aestivation, development, instar, duration, flocculent

Hesperia juba (Scudder) and *Hesperia colorado idaho* (Judder) (Hesperiidae) occupy similar ranges in the Pacific Northwest and are often found flying in the same habitats (Pyle 2002, Warren 2005). Similarly marked and sized, the two species can be confused, particularly when individuals have aged. Whilst the taxonomy of *H. juba* is straightforward with no described geographic variation across its large North American range, this is not the case with *H. colorado idaho* (Warren 2005). *Hesperia c. idaho* is part of the *Hesperia comma* (L.) complex, with many described species and subspecies occurring across boreal North America and Eurasia (Forister *et al.* 2004). In areas east of the Cascade Mountains in Washington State and Oregon, *H. c. idaho* is the widespread phenotype (Pyle 2002, Warren 2005). The immature stages and biology of both species are not well known, and since the landmark publication on *Hesperia* spp. by MacNeill (1964) have only received sporadic attention. No detailed images of immature stages have been published except for a color

photograph of a late instar larva of *H. juba* in Allen *et al.* (2005). A late instar larva of *H. comma* is also illustrated in the same publication. The overwintering biology of *H. juba* has been a subject of conjecture since Shapiro (1980) suggested that it overwinters as an adult in high montane areas of California. Circumstantial evidence for adult overwintering was provided by Berkhausen & Shapiro (1994), who found pollen grains of autumn-flowering rabbitbrush (*Chrysothamnus*) on spring-collected butterflies. Scott (1992) and Warren (2005) did not accept this idea and suggested eggs or larvae as the overwintering stage, but again only presented circumstantial evidence. Other biological and ecological studies on the two species are few (Warren 2005).

The current study was conducted as part of a larger study describing the immature stages and biology of Pacific Northwest butterflies (James & Nunnallee in prep.). During 2005–2006, *H. juba* and *H. c. idaho* were reared in the laboratory, and all immature stages (including each larval instar) were photographed. Notes

on coloration, patterning and sizes of larval instars and pupae were also made. Information was also obtained on aspects of biology such as overwintering, diapause and developmental duration.

MATERIALS AND METHODS

Gravid females of *H. juba* were obtained in late May 2005 (1 female), mid-October 2005 (2) and mid-September 2006 (8) from near the Tucannon River, 25km southeast of Dayton, WA, Snake River Junction, 15 km northeast of Pasco, WA and Waterworks Canyon, 35km northwest of Yakima, WA, respectively. Gravid females of *H. c. idaho* were obtained in late June 2005 (2) and late August 2005 (1) from Bear Canyon, 48km west of Yakima, WA and along the Grande Ronde River road, approximately 20km east of Troy, OR, respectively. Females were placed in plastic boxes (30 × 23 × 8cm) with muslin-covered lids and held under natural lighting/daylengths and temperatures between 20 and 30 °C. Butterflies were provided with potted or cut grass (*Setaria glauca* L.) and paper toweling as oviposition substrates. Tissue pads soaked in sugar/water solution were provided for nourishment. Butterflies oviposited freely under these conditions. Eggs were measured, photographed and transferred to plastic Petri dishes (13cm diameter). First-third instar larvae were reared in the same-sized Petri dishes, provided with cut grass and examined daily or on alternate days except when overwintering. Later instars and pupae were reared in plastic boxes with muslin lids (30 × 23 × 8cm). The spring–summer generation (May–August) of *H. juba* was reared under temperatures of 20–30°C and natural daylengths.

Overwintering. Eggs of *H. c. idaho* were held from oviposition in July or August until October 1 at temperatures between 20–30 °C under naturally declining daylengths. From October 1, they were stored in outdoor ambient conditions until transferred during January–February to 25 ± 0.5 °C and constant fluorescent illumination. Eggs of *H. juba* laid in October 2005 were overwintered in outdoor ambient conditions of temperature and photoperiod. Larvae that hatched in February–March were reared at 15–22 °C and 13h daylength. Eggs and larvae of *H. juba* obtained from oviposition in September 2006 were held in outdoor ambient conditions until November 23 when they were transferred to conditions of 15–22 °C and 13h daylength.

All larval instars and pupae were measured and photographed. Observations on larval morphology, coloration, behavior, development, predation and mortality were made throughout rearing. Photographs were taken using a Canon EOS 1DS Mark II, digital

SLR camera mounted on a tripod. A Canon MP-E 65mm 1X – 5X macro lens was used together with a Macro Twin Lite MT – 24 EX flash lighting system.

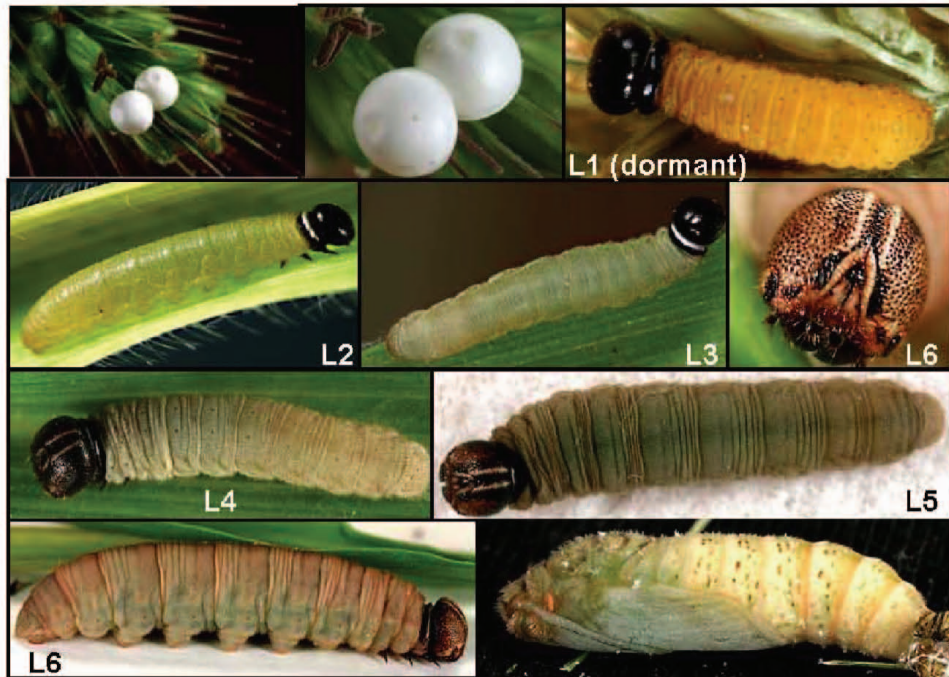
RESULTS

Morphology of immature stages. Eggs, larval instars and pupae of *H. juba* and *H. c. idaho* are shown in Fig. 1 and their dimensions presented in Table 1. The descriptions presented here are brief, focusing on differences between the species. A detailed description of the immature stages of *H. juba* is provided by McNeill (1964).

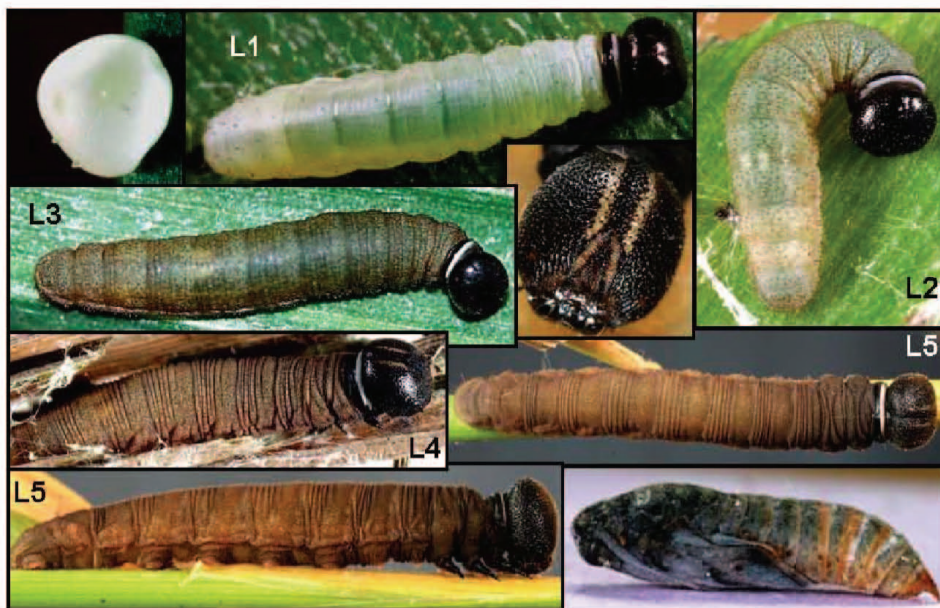
Eggs of both species were creamy white with a pinkish tint developing after 5–7 days. Prior to emergence, the micropyle darkened and, if eggs were examined from underneath, the embryonic larva was visible. The surface of *H. c. idaho* eggs was more prominently reticulated than *H. juba* eggs. Larvae emerged after biting away the micropylar area, sometimes taking 2–3 days from appearance of the larval head until exit. First instar *H. c. idaho* were pale yellow/green (non-dormant) or yellow-orange in non-feeding, overwintering individuals (Fig. 1). Dormant and non-dormant first instar *H. juba* were creamy-white with a greenish tinge developing after feeding. Head capsules of both species were black. Second instar *H. juba* were creamy white with a fine peppering of dark spots. Second instar *H. c. idaho* were yellowish with a peppering of dark spots. Head capsules of both species were black and the cervical shield was conspicuously white-margined anteriorly, a characteristic that persisted during the remainder of larval development. Third instar *H. juba* were dark brown and *H. c. idaho* yellowish-green. Fourth instar *H. juba* were dark brown with an indistinct dorsal black stripe and distinct peppering of minute black spots. Fourth instar *H. c.*

TABLE 1. Sizes (mm) of immature stages of *Hesperia juba* and *Hesperia colorado idaho*. Egg dimensions are height × width. Larval dimensions are lengths measured at commencement and end of each instar. Egg and larval data obtained from examination of 2–4 individuals. Variation was generally less than 0.1mm. Pupae measured from cremaster to tip of head (Mean ± SE). Number of pupae examined in parentheses.

	<i>H. juba</i>	<i>H. c. idaho</i>
Egg	1.0 x 1.3	0.9 x 1.3
First instar	2.5 - 5.0	2.5 - 5.0
Second instar	5.0 - 10.0	5.0 - 8.0
Third instar	10.0 - 16.0	8.0 - 11.0
Fourth instar	16.0 - 21.0	11.0 - 17.0
Fifth instar	21.0 - 30.0	17.0 - 25.0
Sixth instar	-	25.0 - 30.0
Pupa	20.5 ± 0.5 (4)	21.5 ± 0.5 (5)



Hesperia colorado idaho



Hesperia juba

FIG. 1. Life stages of *Hesperia juba* and *Hesperia colorado idaho*

idaho were pale tan with no dorsal black stripe. Minute black spots were less distinct than in *H. juba*. Head capsules had distinct pale, vertical parallel stripes with a pale inverted 'V' at their base, more pronounced in *H. c. idaho*. Head capsules were black in *H. juba*, dark brown in *H. c. idaho*. Fifth instar *H. juba* were dark orangish-brown with six transverse ridges on the posterior half of each abdominal segment. Fifth instar *H. c. idaho* were olive-brown to gray with five transverse ridges on each segment. The indistinct dorsal black stripe of fourth instar *H. juba* was virtually absent in the fifth instar, but present in fifth (and sixth) instar *H. c. idaho* (Fig. 1). The vertical parallel head capsule stripes and lower inverted 'V' were more pronounced in the fifth instar of both species. Additional broad pale areas in the occipital regions occurred in *H. c. idaho* while head capsule ground color remained uniformly black in *H. juba* (Fig. 1). Light brown-orange pigmentation replaced the olive cast in sixth instar *H. c. idaho* and the head capsule was light brown due to expansion of the pale occipital area markings (Fig. 1). Final instars of both species developed two pairs of patches of a white flocculent secretion on the ventral surface between abdominal segments 7 and 8, and 8 and 9 (Fig. 2). The pupae of *H. juba* were dark brown-black, particularly the head and thorax with intersegmental light brown-orange banding on the abdomen. The pupae of *H. c. idaho* were lighter, greenish-yellow to tan with few darker markings. The dorsal surface of the thorax was characterized by two wavy, transverse black lines, one of which approximated a 'W' shape. Brown-black dashes were present on the abdominal segments (Fig. 1). Mature larvae of *H. juba* measured 30mm in length prior to pupation. Larvae of *H. c. idaho* that completed six instars also measured 30mm, while those that pupated after the fifth instar measured 25mm. Pupae of both species measured 20–22mm (Table 1).

Biology of immature stages. Oviposition by females of both species generally occurred within 24–48h of caging. Durations of immature stages of both species are shown in Table 2. Both species were reared on *Setaria glauca* (L.) and *Elytrigia repens* (L.) (Poaceae). Both species suffered from predation in culture by the minute pirate bug, *Orius tristicolor* (White) (Hemiptera: Anthocoridae). Both nymphs and adults of *O. tristicolor* preyed on early instar (1–3) larvae. Grass blades silked together to form shelters did not appear to provide good protection against these small (0.5–2.0mm) predators. Appearance of these predators in the larval cultures was thought to have occurred by inadvertent collection of anthocorid eggs oviposited within stems of field-collected grass.

***H. juba*.** Eggs laid in May 2005 and September 2006 took 10–11 days to hatch at temperatures between 20–30°C. In contrast, virtually all eggs laid in mid October 2005 entered dormancy and did not hatch until the following February or March (Table 2). One egg in this cohort (N = 25) hatched in 14 days and overwintered as a first instar larva (see below). Overwintering eggs contained fully developed embryonic first instar larvae, indicated by conspicuous darkening of the micropyle and verified by dissection. Hatching of overwintered *H. juba* eggs was staggered, occurring over a six week period. Development of early instar larvae in the spring (May 2005) cohort was initially rapid with fifth instar reached within four weeks (Table 2). All instars silked grass blades together to form shelters, with construction more complex in each successive instar. Ecdysis invariably occurred within these shelters. First instars simply wove a few silken strands into a vague 'nest', while pre-pupal final instars constructed tightly webbed shelter tubes. Nest-building characteristics may differ under natural conditions (MacNeill 1964). Fifth instar larvae entered an apparent



FIG 2. Ventral glands and white flocculent secretion in *H. colorado idaho*

TABLE 2. Developmental durations (days) for eggs, larvae and pupae of three cohorts of *Hesperia juba* and two cohorts of *Hesperia colorado idaho*. Instar duration data obtained from first appearance of each instar among species cohorts. Rearing conditions: *H. juba* (May): 20–30 °C and natural daylength. (September): outdoor ambient (for eggs-second instar until Nov 23. L2-adult, 15–22 °C/13h daylength. (October): Outdoor ambient for eggs. L1-adult, 15–22 °C/13h daylength. *H. c. idaho*: eggs - July–Sept 20–30 °C/natural daylength, Oct–Feb outdoor ambient. L1-adult - 25 ± 0.5 °C/24h light.

	<i>H. juba</i> May cohort	<i>H. juba</i> September cohort	<i>H. juba</i> October cohort	<i>H. c. idaho</i> Bear Cyn cohort	<i>H. c. idaho</i> Troy, OR cohort
Egg	10	10	150-170 ^a	45-225 ^a	200-210 ^a
First instar	7	7	7	14-160 ^a	10
Second instar	10	74 ^a	10	7	8
Third instar	10	10	10	9	9
Fourth instar	10	11	10	9	9
Fifth instar	31 ^a	12	12	12	27 ^a
Sixth instar	—	—	—	46 ^a	—
Pupa	15	16	15	18	13
Egg- Adult	93	140 ^a	214-234	320-330	276-286

^aSecond instars prematurely exposed to warm temperatures/long daylengths in late November.

Under natural conditions dormancy continues for another 60–80 days.

^a Dormant stages (hibernal diapause or aestivation)

dormancy in early-mid July, becoming very dark colored, sheltering within grass shelters and not feeding. Dormancy lasted approximately a month with pupae formed from August 10–15. Pupation occurred within a silken cocoon liberally decorated with the flocculent material produced by the ventral abdominal glands. Adult eclosion occurred from August 25–31. The single autumn-hatched larva in 2005 (October 28) fed briefly becoming light green, but was dormant and non-feeding after one week. The larva died in February. The autumn-hatched larvae in 2006 (September 26–28) developed rapidly at first becoming second instars by October 2. Thereafter, feeding decreased and development slowed. By the end of October, most larvae were dormant, non-feeding, mature second instars, resting in silked larval shelters or exposed on grass blades. Inspection of the cohort on November 23 showed substantial mortality with only 2 of ~100 larvae still alive. Temperatures in early November fell to -10°C for a brief period. The two surviving larvae began feeding immediately after exposure to temperatures of 15–22°C developing to pupation (with no final instar dormancy) after 37 days and adults after 51 days.

H. c. idaho. The majority of eggs laid in either July or August 2005 remained dormant until January–March held under ambient outdoor conditions. However, a small number of the Bear Canyon cohort of eggs hatched after 45–65 days during late August and September, into dormant, yellow-orange non-feeding first instars (Fig. 1). None of the Grande Ronde egg

cohort hatched before overwintering. Dormant larvae produced slight webbing to cover themselves. Dormant larvae provided with fresh host grass during October refused to feed but rasped the grass surface to obtain water droplets which they imbibed. Overwintering eggs contained fully developed embryonic larvae as indicated by dark micropyles and verified by dissection. A few larvae from both egg cohorts hatched under outdoor ambient conditions during January and February. Most (~95%) eggs transferred to warm, summer-like conditions (25 ± 1°C and continuous illumination) during January–February did not hatch but remained viable. Dissection of unhatched eggs after more than a month in warm temperatures revealed live but apparently dormant larvae. Eighteen larvae were reared, eight of which overwintered as eggs and ten as dormant first instars. Development of larvae from both cohorts occurred rapidly at 25 ± 0.5°C, reaching fifth instar after 36–39 days (Table 2). Larvae in the Grande Ronde River cohort remained as fifth instars for 27 days before pupating. Larvae in the Bear Canyon cohort spent only 12 days as fifth instars but entered a sixth instar. This instar persisted for 46 days before pupation. Thus, both species appeared to exhibit dormancy in the final instar. *H. c. idaho* larvae were similar to *H. juba* in silken shelter construction. On one occasion, a *H. c. idaho* larva removed paper toweling used as water jar plug and constructed a shelter from it. Pre-pupal ‘wandering’ was observed in some *H. c. idaho* larvae.

DISCUSSION

This is the first published study that comprehensively and pictorially compares all the immature stages of *H. juba* and *H. c. idaho*. It also improves our knowledge of aspects of the biology of the immature stages of these two common Pacific Northwest skipper butterflies. The larvae and pupae show differences in coloration sufficient to provide a reasonable guide to identification. In general *H. juba* larvae were darker colored than *H. c. idaho* and retained a black head capsule throughout development. In contrast, *H. c. idaho* larvae were lighter colored with a progressive increase in pale coloration of the head capsule as larvae matured. No doubt variations in coloration occur within and between regional populations of this subspecies. A late instar larva of the closely related *H. comma* (from Quebec, Canada) shown in Allen *et al.* (2005) appears very similar to *H. c. idaho*. Recent rearing of *H. comma manitoba* (Scudder) showed all larval stages to be colored and marked similarly to *H. c. idaho*, although pupae were darker (James & Nunnallee in prep.). Two well-separated populations of *H. juba* and *H. c. idaho* (eastern slopes of the Cascades and foothills of the Blue Mountains) were studied in this paper and little difference in larval coloration was detected amongst and between the cohorts. There is strong agreement between the images provided here and the meticulous description of immature *H. juba* provided by MacNeill (1964). However, the image of a late instar *H. juba* larva from central California in Allen *et al.* (2005) appears more orange/light brown than the larvae reared in this study. Emmel & Emmel (1973) describe fifth instars of southern California *H. juba* as 'cream colored', suggesting a trend to lighter colored larvae may occur in southern populations of this species.

Both species appear to have the ability to overwinter as eggs or early instar larvae under Pacific Northwest conditions. The identity of the overwintering stage of *H. juba* has been debated since 1980 when Shapiro (1980) suggested it overwintered as an adult in montane areas of California. Berkhausen & Shapiro (1994) found pollen grains from autumn-flowering *Chrysothamnus* on worn spring adults of *H. juba* and suggested this was evidence for adult overwintering. Scott (1992) disputed this idea as did Warren (2005), both indicating it was more likely that overwintering occurred in the egg or larval stage. However, both authors had only circumstantial evidence for this. Scott (1992) showed *H. juba* larvae developed rapidly and concluded there was plenty of time for autumn-oviposited eggs to mature into adults by early-mid spring. Warren (2005) observed freshly-eclosed *H. juba* adults in April at low elevations

in Oregon followed by the appearance of worn individuals some weeks later at higher elevations. He concluded that spring *H. juba* are short or even long distance migrants seeking higher elevations, thus accounting for Shapiro's (1980) observations of worn individuals in spring in Californian mountains. This study has shown that *H. juba* in Washington may overwinter either as a fully developed egg or a first instar if oviposited in mid-October, or as a second instar if eggs are laid in mid-September. Eggs laid in early September may hatch and the larvae overwinter as third instars. The rapid development shown by overwintering second instars when transferred to warm temperatures confirms Scott's (1992) assumption that sufficient time is available for complete immature development before April–May. Overwintering larvae likely have the competency to re-commence feeding whenever conditions allow during January–February. Overwintering eggs of *H. juba*, like first instars, appear ready to exploit favorable conditions in January–February, with staggered hatching occurring during this period. The impact of winter temperatures on survival of *H. juba* eggs and larvae is unknown. The cold temperatures (-10 °C) experienced by the 2006 cohort of overwintering larvae, which presumably resulted in the observed high mortality, was unusually early (Nov 1–2) and the larvae may not have fully entered dormancy at this point. These data along with the data and observations of Scott (1992) and Warren (2005) indicate that it is most likely that *H. juba* in the Pacific Northwest overwinters as an egg or early-mid instar larva. Confirming the observations of Warren (2005), studies on spring populations of *H. juba* in the Columbia Basin of eastern Washington during 2003–06 showed individuals captured in April were always in a freshly-eclosed condition (James unpubl. obs.).

Overwintering of species in the *H. comma* complex, including *H. c. idaho*, is reported to occur in the egg stage (Hardy 1954, Scott 1986, Allen *et al.* 2005) over most of its temperate range, although older larvae or pupae also overwinter in the Arctic where the species is biennial (Scott 1986). In this study, *H. c. idaho* mostly overwintered as fully developed eggs, but a significant number of larvae in one cohort (from the eastern Cascades) also overwintered as first instars. Overwintering first instars were distinctively colored (yellow-orange) compared to first instars emerging from overwintered eggs (pale yellow-green). The conditions used in this study (25 °C and continuous illumination) to break dormancy in overwintering stages appeared to be sub-optimal for *H. c. idaho* eggs. Very few hatched under these conditions, most remaining dormant but

apparently viable. Possibly the 'long day' lighting regime was inhibitory to hatching, signaling perhaps (under holarctic conditions) too short a period to complete immature development. Under natural conditions, long photoperiods may be involved in preventing summer egg hatch in the majority of individuals. Exposing overwintered eggs of the closely related *H. comma manitoba* to 25 °C and 12 hours of light resulted in >90% hatch (James & Nunnallee in prep.). The overwintering strategies of both *H. juba* and *H. c. idaho* appear to be flexible with diapause not fixed or confined to a single stage. This flexibility clearly confers advantages in terms of optimizing development under marginal temperature conditions.

A second period of dormancy or summer diapause (aestivation) during development was observed in both species and reported for the first time for the genus *Hesperia*. Final instar larvae of *H. juba* in the spring generation became quiescent in July–August and remained in their shelters for about a month before they became pre-pupal and pupated. During this apparent aestivation, no feeding occurred. Final instar dormancy did not occur in the overwintered larval generation. Similarly, last instar larvae (fifth or sixth) of *H. c. idaho* also entered a period of non-feeding dormancy, which lasted for about a month in the fifth instar and almost seven weeks in the sixth instar. Sixth instar larvae of *H. comma manitoba* also enter a six week dormancy (James & Nunnallee in prep.). Duration of the final instar in both species was 3–5 times greater than the other individual instars. Although final instar dormancy/aestivation does not appear to have been reported for North American *Hesperia*, Scott (1986) reported that mature larvae of *Ochlodes sylvanoides* (Bosduval) aestivate about a month prior to pupation. MacNeill (1964) indicated that one to two weeks in each instar was normal for *Hesperia* spp. and larvae that spent a greater period of time in one stage invariably died. The function of delayed development in the final instar of *H. juba* and *H. c. idaho* is unclear but is likely to be related to synchronization of adult eclosion with optimal conditions for survival and reproduction. Thus, the normal phenology of *H. juba* in the Pacific Northwest with two distinct adult generations (spring and autumn), suggests that environmental conditions are optimal at these times. If summer was also optimal for *H. juba*, there would likely be a series of overlapping generations from spring to autumn as occurs in the related hesperiid *Atalopedes campestris* in eastern Washington (Crozier 2004). The observations of Warren (2005) concerning a possible late spring migration of *H. juba* from lowland to highland areas in Oregon support the hypothesis that cooler or milder environments are

preferred. Delayed development of final instar *H. juba* prevents adult eclosion occurring in late July/early August, a time characterized by hot, dry conditions in eastern basin areas of Washington and Oregon. Instead, adults emerge in late August/early September when temperatures have moderated. It is likely that the dormancy is controlled by a combination of temperatures and photoperiods experienced by mid-late instars. The final instar dormancy in *H. c. idaho*, presumably serves a similar function, although in this case (in the Pacific Northwest), there is only a single generation. Peak flight period in the Pacific Northwest occurs during July–August into September. Delayed development of *H. c. idaho* presumably allows much of the population to survive into late summer and autumn, minimizing exposure of eggs to hot, dry conditions. Without final instar aestivation it is likely that many individuals would eclose during April–May. Other factors such as host plant quality, pressures from natural enemies, etc. may also have played a role in shaping this strategy. It would be interesting to determine whether other species in the *H. comma* complex which occur in cooler environments also undergo final instar aestivation.

Variation in instar number in *Hesperia* spp. was reported by MacNeill (1964). In his rearings, six appeared to be the normal instar number, but he acknowledged variation between subspecies and even within cohorts from a single female. Larvae of *H. juba* in a single cohort were recorded going through five or six instars in a ratio of approximately 50:50. All individuals of *H. juba* reared in the current study pupated at the end of the fifth instar. One cohort of *H. c. idaho* (Bear Canyon) passed through six instars while individuals in the other cohort (Grande Ronde River) passed through five. *Hesperia comma manitoba* larvae from adults obtained in southern British Columbia developed through six instars (James & Nunnallee in prep.). Instar number variation in some instances may be an artifact of laboratory rearing or associated with diseased individuals that may go through as many as eight instars, but become progressively smaller after the sixth instar (MacNeill 1964).

The two grass species (*S. glauca*, *E. repens*) used for rearing *H. juba* and *H. c. idaho* larvae in this study do not appear to have been previously reported as hosts (Scott 1986, Pyle 2002). In common with many other grass skippers, these species appear to have a wide host range in the Poaceae. Larval hosts for *H. c. idaho* have not been reported in the Pacific Northwest but in Colorado include species of *Bromus*, *Bouteloua*, *Andropogon*, and *Lolium* (Scott 1992). Species of *Bromus*, *Poa*, *Deschampsia* and *Stipa* have been

recorded as hosts for *H. juba* (Scott 1986). The white flocculent secretion produced by ventral glands in the final instar of both species has been reported for a number of hesperiids (Dethier 1942, MacNeill 1964) but has rarely been illustrated (Fig. 2), (but see pages 133 and 137 in Allen *et al.* (2005)). The secretion appears to serve as a moisture repellent. Dethier (1942) showed that the secretion is insoluble in water and repels water. The secretion was readily incorporated into the pupal shelters or loose cocoons formed by final instar *H. juba* and *H. c. idaho*, where it presumably helps protect the pupae from excessive moisture.

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LITERATURE CITED

- ALLEN, T. J., J. P. BROCK, & J. GLASSBERG. 2005. Caterpillars in the field and garden. Oxford University Press, New York. 232 pp.
- BERKHOUSEN, A. E. & A. M. SHAPIRO. 1994. Persistent pollen as a tracer for hibernating butterflies: The case of *Hesperia juba* (Lepidoptera: Hesperidae). *Great Basin Naturalist*. 34 (1): 71–78.
- CROZIER, L. 2004. Field transplants reveal summer constraints on a butterfly range expansion. *Oecologia* 141: 148–157.
- DETHIER, V. G. 1942. Abdominal glands of Hesperinae. *J. New York Ent. Soc.* 50 (2): 203–206.
- EMMEL, T. C. & J. F. EMMEL. 1973. The butterflies of Southern California. *Nat. Hist. Mus. of Los Angeles Co. Science Series* 26: 1–148.
- FORISTER, M. L., A. FORDYCE, & A. M. SHAPIRO. 2004. Geological barriers and restricted gene flow in the holarctic skipper *Hesperia comma* (Hesperidae). *Mol. Ecol.* 13: 3489–3499.
- HARDY, G. A. 1954. Notes on the life history of *Hesperia comma* L. *manitoba* Scud (Lepidoptera: Rhopalocera) on Vancouver Island. *Ent. Soc. Brit. Col. Proc.* 51: 21–22.
- JAMES, D. G. & D. NUNNALLEE. In prep. Life histories of Cascadia butterflies. Oregon State University Press.
- MACNEILL, C. D. 1964. The skippers of the genus *Hesperia* in western North America with special reference to California. University of California Publications in Entomology, University of California Press, Berkeley and Los Angeles. 35: 1–221.
- PYLE, R. M. 2002. The butterflies of Cascadia. Seattle Audubon Society. 420 pp.
- SCOTT, J. A. 1986. The butterflies of North America. Stanford University Press, Stanford. 583 pp.
- . 1992. Host plant records for butterflies and skippers (mostly from Colorado) 1959–1992, with new life histories and notes, oviposition, immatures and ecology. *Papilio* (New Series) 1–182.
- SHAPIRO, A. M. 1980. Does *Hesperia juba* (Hesperidae) hibernate as an adult? *J. Lep. Soc.* 33(4): 258–260.
- WARREN, A. D. 2005. Butterflies of Oregon, their taxonomy, distribution and biology. *Lepidoptera of North America* 6. Contributions of the C. P. Gillette Museum of Arthropod Diversity. Colorado State University, Fort Collins. 408 pp.

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