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## A Revision of the North American *Salix*-feeding *Colias* Species (Pieridae: Coliadinae)<sup>1</sup>

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### INTRODUCTION

For nearly a century, various authors have confused the species *Colias scudderi* Reakirt and *Colias gigantea* with one another, and with *Colias pelidne* Boisduval & Le Conte and *Colias christina* [= *alexandra christina*] W. H. Edwards. Anyone having observed these insects in the field experiences no such difficulty. The geographic range of *scudderi* does not overlap with those of *pelidne* and *alexandra christina*. *C. scudderi* reaches its northern limit in S.E. Wyoming, and is separated by the Great Divide Basin from the southern limits of the ranges of *C. pelidne*, *C. gigantea* and the yellow-orange and orange races of *C. alexandra*.

Both *scudderi* and *gigantea* occur in very moist habitats where their larval hosts, *Salix* sp., occur. Adults are often encountered in deep bog areas where the willow roots are actually submerged. *C. pelidne* and *C. alexandra* normally inhabit drier environments, although males of both species may wander into bogs.

Although some females of *alexandra christina* and *gigantea* may be confused on an individual basis, the males are easily separated. Males of *gigantea* are always pure lemon yellow dorsally, while those of *christina* always manifest some strong orange patches. Females of *gigantea* range from yellow (sometimes orange-flushed) to white, while those of *christina* may range in dorsal color from orange through yellow into white. The FW apices of *christina* are more acute and sharply defined than those of *gigantea*, *pelidne*, and *scudderi*. Adults of *alexandra christina* frequent open meadows and cleared areas in woodlands, with males often patrolling roads, fire cuts and power line rights of way. Members of the Leguminosae serve as larval hosts. *C. pelidne* occupies habitats similar to those of *christina*, but the larval hosts are members of the Ericaceae. In the Far North, *pelidne* occurs over open tundra.

The only overlaps of the ranges of *pelidne* and *gigantea* are in portions of the Rocky Mts. and intermittently in the western arctic. *C. gigantea* is distributed from northern Wyoming, Manitoba, and the western coasts of James and Hudson's Bays in Ontario westward and northward into Alaska. *C. pelidne* is common in Newfoundland and the eastern arctic, but in western North America, it is found in numbers only in the Rocky Mts. from western Wyoming northward into Alberta and British Columbia, with a few records from the Yukon Territory.

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Adults of both *gigantea* and *pelidne* are dorsally bright lemon yellow in the males, while the females may be either yellow or white. Normally *gigantea* is much larger in size than *pelidne* and the two species usually can be separated on this basis alone. The VHW discal spot is diagnostic, being in *gigantea* generally large with a well-defined pupil, and frequently double (with a superior satellite spot). In *pelidne*, this spot is small and heavily rimmed by dusty-rose scales. Very rarely there is a trace of a superior rosy punctate spot.

#### SEPARATION OF *Colias scudderi* FROM *Colias gigantea*

Although from time-to-time various authors have treated *gigantea* as a subspecies of *scudderi*, they appear to be distinct species, and may be separated on the basis of geographic

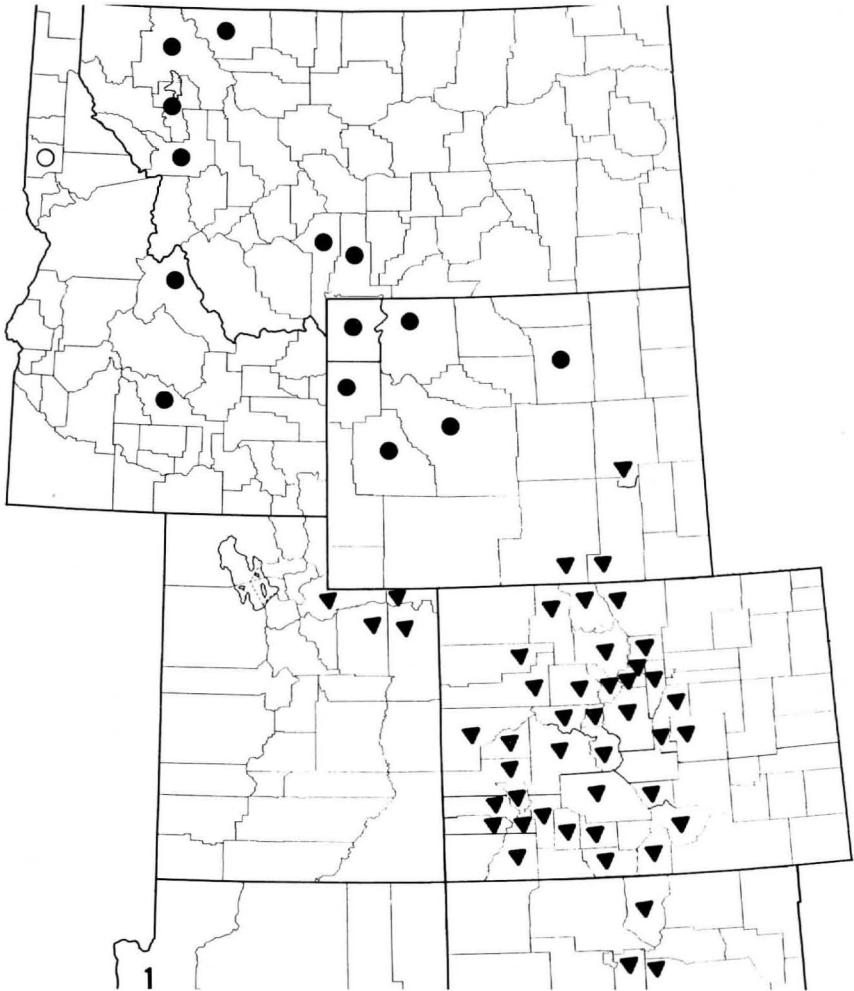


Figure 1: Distribution map for *Colias scudderi* (triangles) and *Colias gigantea harroweri* (circles). The open circle denotes an extinct colony in Latah Co., Idaho.

distribution, habitat association, and general morphology. Figs. 1 and 2 are distribution maps for these two species. *C. scudderi* is exclusively an alpine butterfly that occurs generally above 9000' (2750 m) in willow-bog environments. It ranges from the southern Sangre de Cristo Mts. of northern New Mexico through the Rocky Mt. massif of Colorado into the Sierra Madre Range, Medicine Bow Mts., and Laramie Range in S.E. Wyoming. An offshoot of this distribution appears in extreme N.E. Utah. The Great Divide and Shirley Basins of Wyoming separate the northern limits of *scudderi* from the southern limits of *gigantea*. While the geographic distribution of *scudderi* is compact, that of *gigantea* is diffuse. The latter species ranges from Wyoming northward through part of Idaho and western Montana into the Rocky Mts. of British Columbia and Alberta, thence to the north and west into the Northwest Territories, Yukon Territory and Alaska. It diffuses across Saskatchewan and Manitoba into N.W. Ontario along the shores of Hudson Bay and James Bay. An apparently relict population occurs in the Ochoco Mts. in Oregon. With the exception of several colonies in the Big Horn and Wind River Mts. in Wyoming which occur at 9000' (2750 m), *gigantea* generally is found at considerably lower elevations than *scudderi*, and it lives at sea level in some arctic localities. Of course, one must recognize

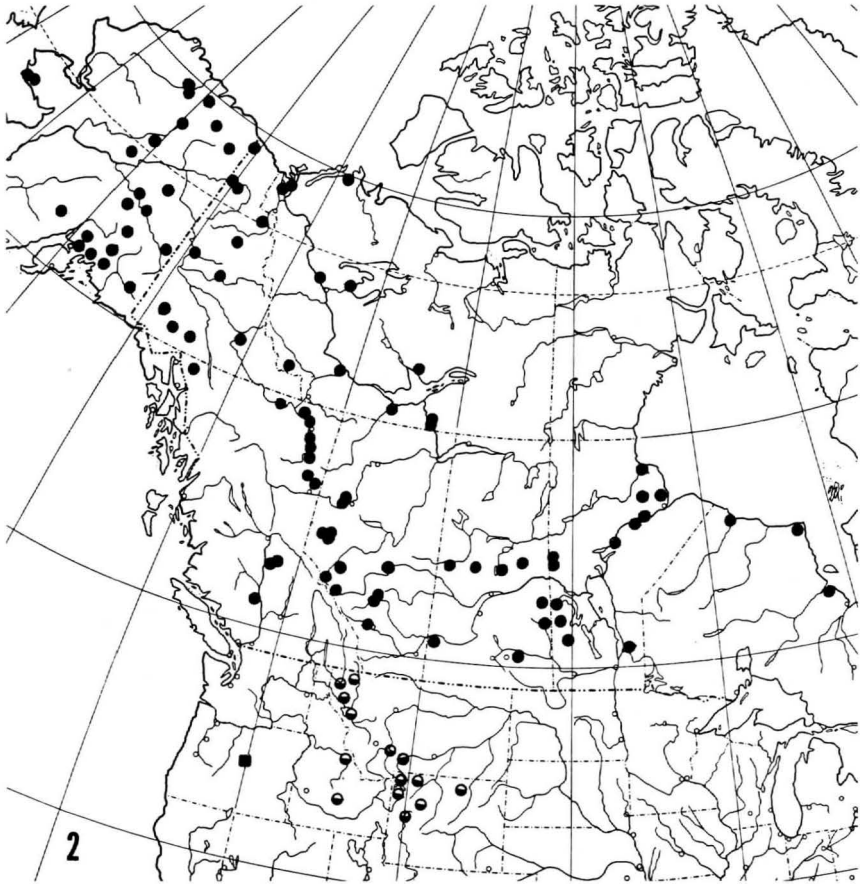


Figure 2: Distribution map for *Colias gigantea*. Solid circles = *C. g. gigantea*. Half-open circles = *C. g. harroweri*. Solid square = Crook Co., Oregon isolate.

that latitude replaces altitude ecologically as one travels north. Even so, colonies in Idaho, Montana, and southern Alberta are generally situated at about 6000' (1800 m). Not all Wyoming colonies are located at high elevations; one in the Absaroka Range in Park Co. occurs at just below 6600' (2000 m). In the arctic, *gigantea* is not one of the montane species. Throughout its range, this butterfly is associated with extremely boggy areas that support heavy growths of willow. It is restricted to montane willow bogs in the southern portion of its range, but occurs widely in moist tundra associations (including bog "eyes" in taiga) northward where scrub willows abound.

These two species have several morphological characters in common including a bright, lemon-yellow ground color in the males, dimorphic females (yellow or white), lack of UV reflectance, and no useful diagnostic characters in the male genitalia. Two morphological characters separate these two species: 1. general size; 2. FW shape. Normally the width of the FW measured at vein  $Cu_2$  is about 3 mm longer in males of *gigantea* and 2.5 mm longer in females relative to the same lengths measured for *scudderi*. The FW are more elongate in *gigantea*. A length-to-breadth ratio has been calculated for both species using the dimensions illustrated in Fig. 3. L is the horizontal wing length measured from the wing base at the thorax to the wing margin at vein  $Cu_2$ . B is the wing breadth measured from the costal margin perpendicular to the inner margin along a line passing through the  $R_4-R_5$  fork. Measurements were taken from specimens of *scudderi* collected in Colorado, New Mexico, Wyoming, and specimens of *gigantea* collected in Alaska, Alberta, British Columbia, Manitoba, Wyoming, and the Yukon Territory. Twenty-five specimens of each sex and species selected at random were measured and the data are tabulated in Table 1. The average horizontal-length-to-breadth ratios ( $R = L/B$ ) were calculated for both sexes of each species. This ratio is larger in *gigantea* as compared to *scudderi* significant at a level  $p < 0.0001$  (thus very highly significant) based upon a standard t test.

Although the species *scudderi* and *gigantea* appear to be closely related, it is concluded on the basis of the above that they are indeed separate. To summarize, the following factors are significant: 1. The FW shape differs between the two species as indicated by the R ratios tabulated in Table 1. The FW is significantly more elongate in *gigantea* as compared to *scudderi*. 2. Habitat difference. Although both species occur in bogs or along streams that flow through bogs, there is a subtle habitat difference. *C. scudderi* normally occurs in the upper Canadian and lower Hudsonian zones. On the other hand, when it occurs in montane habitats, *C. gigantea* occurs in transition zone or lower Canadian zone bogs.

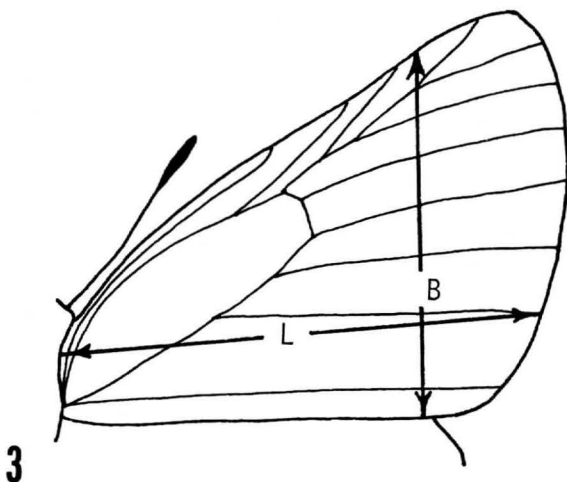


Figure 3: Wing dimensions used in obtaining data shown in Table 1.

These habitats are located in open coniferous forest close to aspen-sagebrush environments. One site in Idaho for *C. gigantea harroweri*, although located at an elevation of 6700' in the foothills of the Bitterroot Range, is ecologically upper Sonoran desert which surrounds a large open bog. 3. As noted also in Table 1, *C. gigantea* is significantly larger in size than *C. scudderi*. Additional data are presented in Table 3. 4. The color of the females in the populations of *gigantea* (ssp. *harroweri*) geographically closest to the northernmost colonies of *scudderi* is significantly different. The dorsal color in *scudderi* varies from lemon-yellow to white. In *gigantea*, the yellow examples are flushed with orange, and the white examples (when fresh) have a creamy yellow-orange flush. The dark "Colias" FW borders are consistently better developed in these *gigantea* populations as compared to *scudderi*.

The separation between these two species is theorized to have occurred toward the end of the Pleistocene.

TABLE 1  
MORPHOMETRIC DATA FOR *Colias scudderi* and *Colias gigantea*

L = horizontal wing length measured along vein Cu<sub>2</sub>.

B = wing breadth measured through R<sub>4</sub>-R<sub>5</sub> fork from costal margin perpendicular to inner margin.

	<i>scudderi</i> <sup>1</sup>			<i>gigantea</i> <sup>2</sup>		♂ ♀
	♂ ♂	♀ ♀	♂ ♀	♂ ♂	♀ ♀	
N	25	25	50	25	25	50
L <sub>max</sub>	22.0 (mm)	22.0 (mm)		24.0 (mm)	23.0 (mm)	
L <sub>min</sub>	16.5	18.5		19.5	20.5	
B <sub>max</sub>	16.0	17.0		17.5	18.5	
B <sub>min</sub>	13.5	13.5		14.0	14.5	
R <sub>max</sub> <sup>3</sup>	1.375	1.370		1.500	1.500	
R <sub>min</sub>	1.100	1.100		1.229	1.216	
L <sub>av</sub>	18.58	20.04	19.31	21.48	22.55	22.015
B <sub>av</sub>	14.99	15.52	15.24	16.00	16.38	16.19
SD <sup>4</sup>	0.0545	0.0524	0.0586	0.0645	0.0582	0.0632
CV <sup>5</sup>	4.386%	4.054%	4.623%	4.797%	4.217%	4.637%
R <sub>av</sub> <sup>6</sup>	1.242±0.0545	1.293±0.0524	1.267±0.0586	1.345±0.0645	1.379±0.0582	1.362±0.0632
	1.242±4.386%	1.293±4.054%	1.267±4.623%	1.345±4.797%	1.379±4.217%	1.362±4.637%

Notes:

1. Specimens from Colo., New Mex., Wyo.
2. Specimens from Alask., Alta., B.C., Man., Wyo., Y.T.
3. R = L/B ratio.
4. Standard Deviation for R = L/B.
5. Coefficient of Variation for R = L/B.
6. Mean calculated from individual L/B ratios.

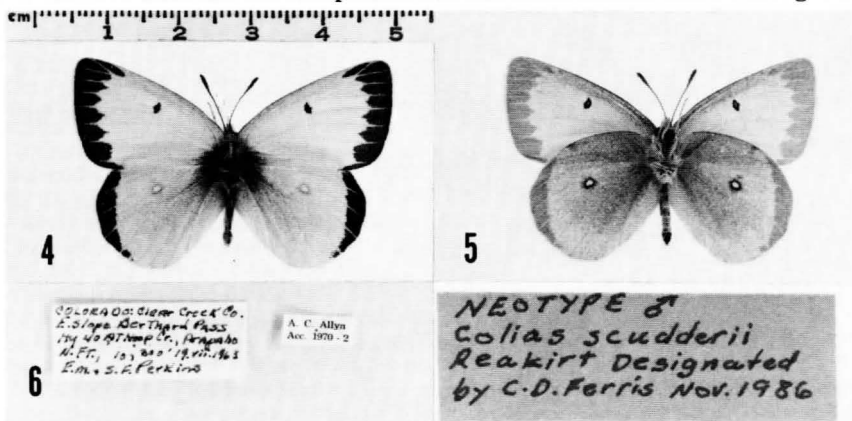
SIGNIFICANCE OF R (MEAN VALUE) DIFFERENCES — t TEST

	♂ ♂	♀ ♀
n	48	48
t	6.08	10.01
p	< 0.0001 < 0.0001	
	p < 0.01 is highly significant.	

*Colias scudderii* Reakirt 1865  
Figs. 4-28

- Colias scudderii* Reakirt, 1865: 217-218. TL — Rocky Mountains, Colorado Territory, Holotype — Lost. Neotype designated herein.  
 = *Colias pelidne* Boisduval & Le Conte; Strecker, 1878: 81. [partim].  
 = *Colias scudderii* var. *flavotincta* Cockerell, 1901: 186-187.  
 = *Eurymus scudderii scudderii* (Reakirt); Dyar, 1902: 10.  
 = *Eurymus scudderii flavotincta* (Reakirt); Dyar, 1902: 10.  
 = *Eurymus scudderii* (Reakirt); Barnes & Benjamin, 1926: 8.  
 = *Eurymus scudderii* ab. "flavotincta" (Cockerell); Barnes & Benjamin, 1926: 8.  
 = *Colias scudderii ruckesi* Klots, 1937: 324-326 [SYN. NOV.].  
 = *Colias scudderii scudderii* Reakirt; McDunnough, 1938: 8.  
 = *Colias scudderii scudderii* ab. "flavotincta" Cockerell; McDunnough, 1938: 8.  
 = *Colias scudderii ruckesi* Klots; McDunnough, 1938: 8.  
 = *Colias gigantea scudderii* Reakirt; Klots, 1951: 187.  
 = *Colias gigantea ruckesi* Klots; Klots, 1951: 187.  
 = *Colias pelidne scudderii* Reakirt; Klots in Ehrlich & Ehrlich, 1961: 57.  
 = *Colias scudderii* Reakirt; McHenry, 1963: 221.  
 = *Colias scudderii scudderii* Reakirt; dos Passos, 1964: 43.  
 = *Colias scudderii scudderii* f. ♀ "flavotincta" Cockerell; dos Passos, 1964: 43.  
 = *Colias scudderii ruckesi* Klots; dos Passos, 1964: 43.  
 = *Colias scudderii scudderii* Reakirt; Miller & Brown, 1981: 83.  
 = *Colias scudderii scudderii* ♀ f. "flavotincta" Cockerell; Miller & Brown, 1981: 83.  
 = *Colias scudderii ruckesi* Klots; Miller & Brown, 1981: 83.  
 = *Colias scudderii scudderii* Reakirt; Hodges *et al.*, 1983: 52.  
 = *Colias scudderii scudderii* ♀ f. "flavotincta" Cockerell; Hodges *et al.*, 1983: 52.  
 = *Colias scudderii ruckesi* Klots; Hodges *et al.*, 1983: 52.

*Colias scudderii* was described by Reakirt in 1865. Note the correct spelling is *scudderii* since this name is a noun in the genitive case formed from a modern personal name [I.C.Z.N. Code, Arts. 31, 32(d)]. Reakirt's original description of this taxon is accurate and complete, and needs no amplification here. The type specimen, however, has been lost. A short biographical account of Reakirt was published by Brown (1964, 1986), in which he noted that Reakirt's collection was incorporated into that of Herman Strecker. Although the



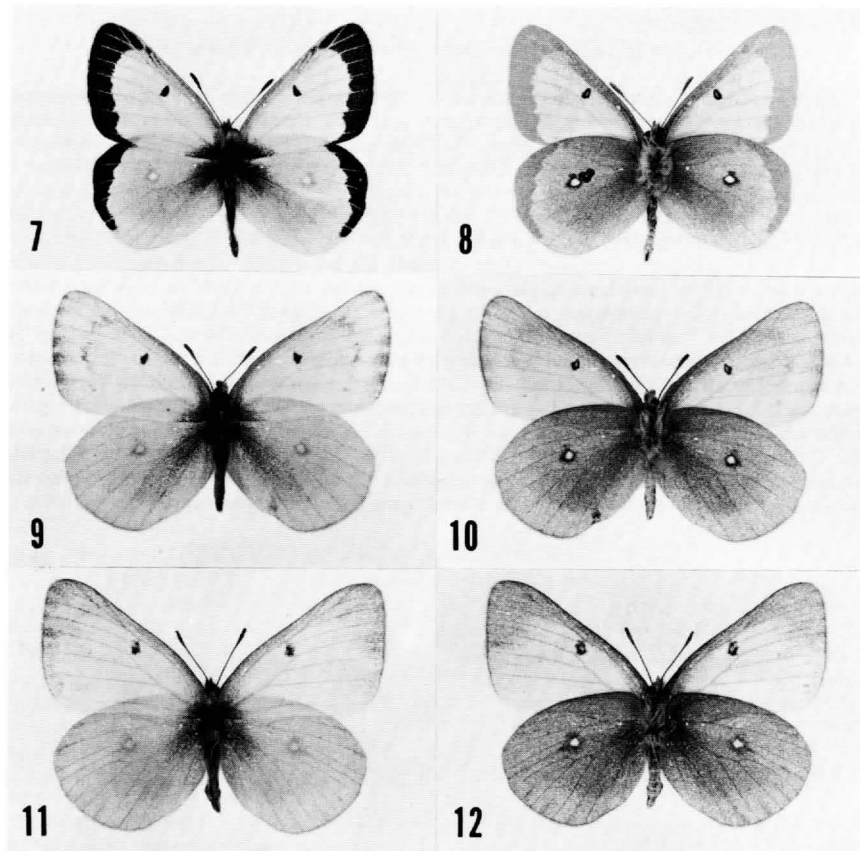
Figures 4-6: Neotype male of *Colias scudderii*. D. (4), V (5) and specimen labels (6). Note misspelling Berthard for Berthoud. Specimen in Allyn Museum of Entomology/Florida State Museum.

Strecker collection is extant in its entirety, the type of *scudderi* cannot be identified among the six males contained therein. Initially Strecker did not accept this taxon as valid and treated it in his 1878 catalogue as a synonym of *pelidne*.

During preparation of Memoir No. 2 of the Lepidopterists' Society (Brown & Miller, 1981), Brown fixed the type locality of *scudderi* as "vic. Empire, Clear Creek Co., Colorado" and so published this information, but he neglected to designate a neotype. To correct this situation, a neotype is now designated. The specimen selected as the neotype is shown in Figs. 4-5, and its pin labels in Fig. 6. It was collected by E. M. & S. F. Perkins, 19 July, 1963 on the east slope of Berthoud Pass along Hwy. 40 at Hoop Creek in the Arapahoe National Forest, 10,800', Clear Creek Co., Colorado. The neotype is placed in the collection of the Allyn Museum of Entomology/Florida State Museum, Sarasota, Florida.

## DISCUSSION

*Colias scudderi* is an extremely variable species. Some morphometric data are presented



Figures 7-12: Typical specimens of *Colias scudderi*. ♂ D (7) and V (8) from Lewis Lk., 10,000', Albany Co., WY, 28.vii.71. Yellow ♀ D (9) and V (10) from Winter Park, Grand Co., CO, 6.vii.67. White ♀ D (11) and V (12) from Snowy Range, 10,000', Albany Co., WY, 6.vii.68. Specimens in C. D. Ferris Collection.

subsequently in Table 2. Both the length of the FW and the nature of the dorsal wing borders vary considerably. Among the specimens studied, the FW length measured along the costal margin from thorax to apex ranged as follows: 21-26 mm ♂♂; 22-26 mm ♀♀. The females are polymorphic in both ground color and maculation. In a study group of 91, 16 were yellow (17.6%), 21 were yellowish-white (23.1%), and 54 were white (59.3%). The wings dorsally vary from immaculate (Fig. 23), lightly marked (Figs. 25, 29), to strongly marked (Fig. 27), with some approximating the full border found in many other *Colias* species (Figs. 9, 28). In both sexes, the VHW discal spot is usually single or manifests the suggestion of a very small superior satellite spot. Occasionally a fully-developed satellite spot is present (Fig. 13).

Based upon extensive study of this taxon, I recognize only the specific epithet *scudderi* without subspecies. In the paragraphs that follow, additional names proposed by several authors are discussed in chronological order.

*Colias scudderi* var. *flavotincta* Cockerell 1901

TL — Lake Co., Colorado. See discussion below.

HT — Fig. 5, plate *COLIAS* VIII, W. H. Edwards, 1887, B.N.A., vol. 1. See discussion below. Lectotype in Carnegie Museum of Natural History.

There has been considerable confusion about the name *flavotincta* because of the manner in which Cockerell described it. From August 1-4, 1901, Cockerell and his wife collected along the "Summit of the range between the Pecos and Sapello rivers, near the headwaters of the Pecos... elevation of about 11,000 ft." [San Miguel Co., New Mexico]. Cockerell did not designate a type specimen, but rather referred to an illustration in Edwards' B.N.A.: "The ♀ is figured (fig. 5) on Edwards' plate in Butt. N.A. Several seen; my wife took a pair." The name applies to the yellow female form of *scudderi* if strictly interpreted. In his 1902 catalogue, however, Dyar treated *flavotincta* as a subspecies. Authors subsequent to Dyar have treated *flavotincta* as both an aberrational name or form name for the female yellow phenotype. According to Arts. 16, 45(g) of the Code, names proposed prior to 1961 as "variety" may be treated either as subspecific or infrasubspecific. In a broad context, *flavotincta* could be treated as a subspecies of *scudderi* from New Mexico, but herein lies an additional problem. By Cockerell's designation, the Edwards illustration must be taken to represent the type. The specimen illustrated by Edwards (allowing for some artistic license) has been located by John E. Rawlins in the Edwards material at the Carnegie Museum of Natural History, and is illustrated in Figs. 14-15. I hereby designate it the lectotype of *Colias scudderi* var. *flavotincta* Cockerell with the accompanying label shown in Fig. 20. Based upon Edwards's associated narrative, it is

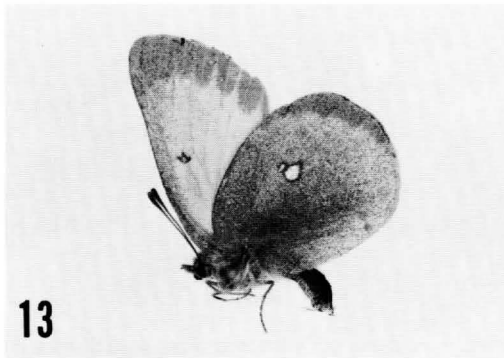
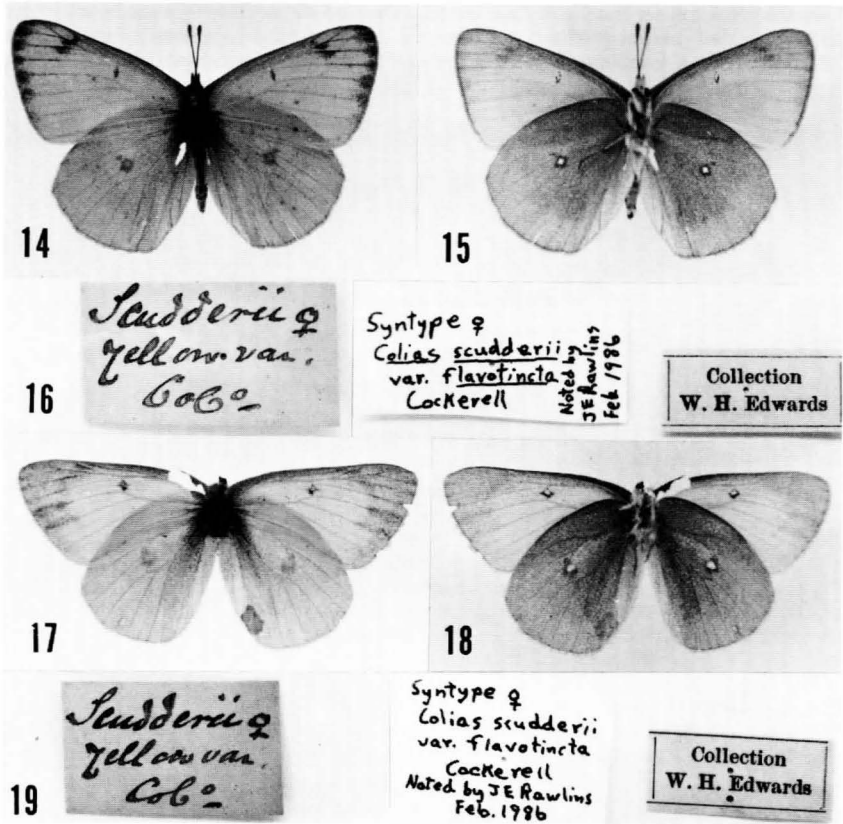


Figure 13: *C. scudderi* ♂ V from T16N, R78W, S17E, 9200', Albany Co., WY, 6.ix.82 showing double VHW discal spot; uncommon in *scudderi*. C. D. Ferris Coll.

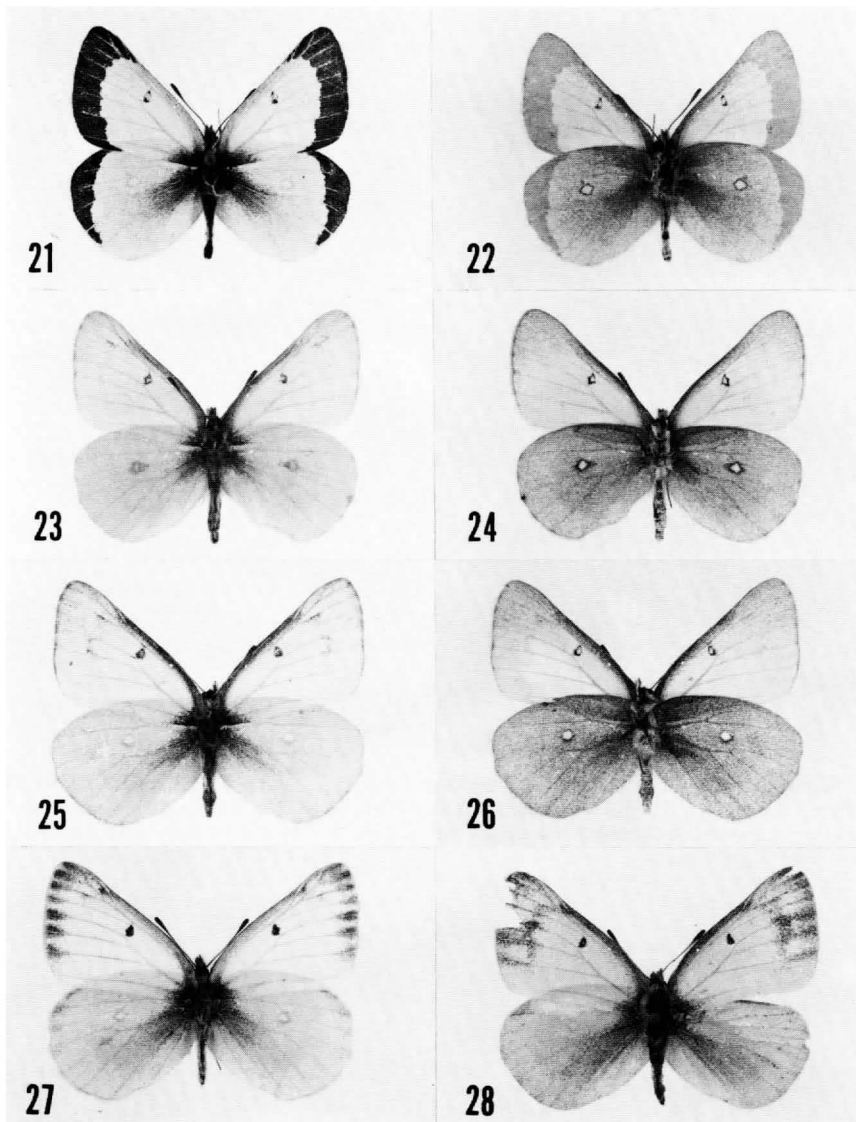




Figures 14-19: Syntype ♀♀ of *Colias scudderii* var. *flavotincta* Cockerell in the W. H. Edwards Coll. at Carnegie Museum of Natural History. D. (14), V (15) and specimen labels (16) of specimen designated the lectotype. D (17), V (18) and specimen labels (19) of additional syntype.

Figure 20: Lectotype label for specimen shown in Figs. 14-16.

inferred that the yellow female specimen illustrated in B.N.A. was collected in Colorado by T. L. Mead, either in the upper Arkansas River Valley or in the vicinity of Twin Lakes [Lake Co.]. This places the TL of *flavotincta* in the central portion of Colorado based upon Cockerell's designation of the type. I hereby designate the type locality as Lake Co., Colorado. Thus if considered to be a subspecies (as first designated by Dyar), then



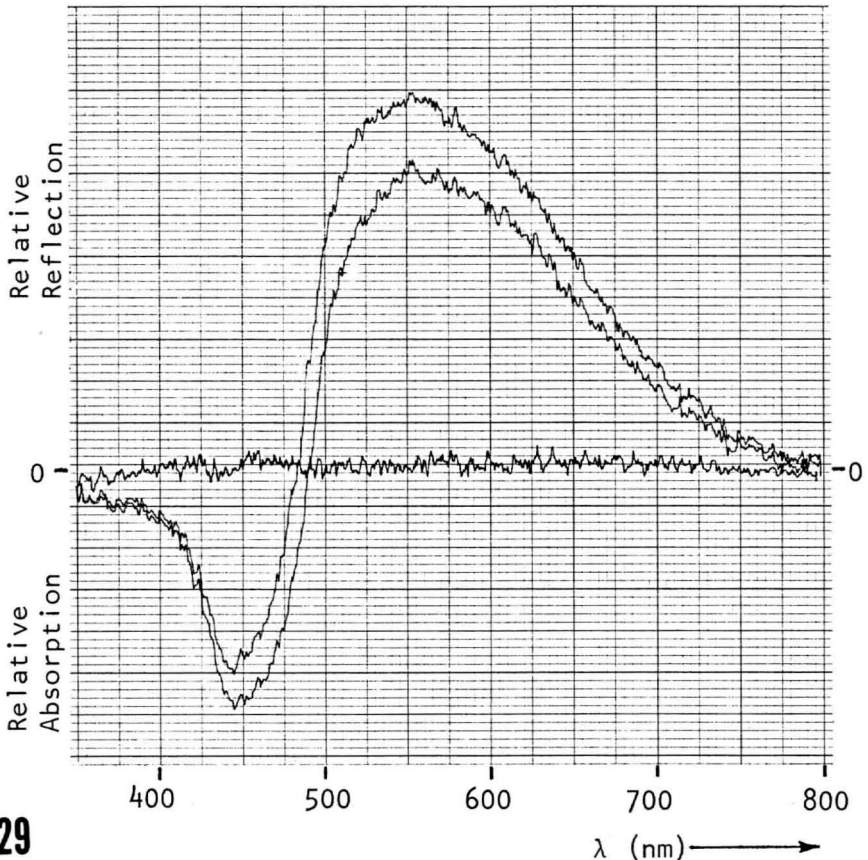
Figures 21-28: *C. s. ruckesi* [= *scudderii*]. ♂ D (21), V (22); yellow ♀ D (23), V (24); white ♀ D (25), V (26); topotypes from Winsor Ck. Can., 9900', Santa Fe Co., NM, 1.vii.74. White ♀ D (27) from Nellie Ck. Tr., 11,000', Hinsdale Co., CO, 26.vii.80. Yellow ♀ D (28) from Cabresto Can., ca. 10,000', Taos Co., NM, 6.vii.74. C. D. Ferris Coll.

*flavotincta* is a junior synonym of *C. scudderi scudderi*. An additional yellow female (and the only other one) from the Edwards collection is shown in Figs. 17-18.

*Colias scudderi ruckesi* Klots 1937  
Figs. 21-28.

TL — Windsor [sic, Winsor] Creek Canyon, west of Cowles, [San Miguel Co.], New Mexico  
HT — Collected by A. B. Klots on 2 July, 1935; in American Museum of Natural History.

Klots described *ruckesi* as a "new geographical subspecies". He completely ignored Cockerell's taxon *flavotincta*. The description of *ruckesi* is detailed and centers about a table of numerical data in which measurements taken of *scudderi* are compared to similar measurements taken of *ruckesi*. It is on the basis of these data that Klots differentiated *ruckesi* from *scudderi*. He made the statement: "Although *ruckesi* is not an extremely well-marked race, I am convinced that it is worth naming. It is not to be expected that in such a race as this every specimen will be distinct from any specimen of another race; and such is the case here". What Klots apparently did not take into consideration is the annual variation that occurs in alpine butterflies, especially in the high elevations of the



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Figure 29: Scan of reflected light intensity from the DFW of two male *C. scudderi* from Santa Fe Co., NM (upper trace) and Albany Co., WY (lower trace).

Rocky Mts. In Table 2, I have presented data from measurements similar to those that Klots published. His original data are reproduced for comparison. With regard to wing measurements, my data show exactly the opposite results from those obtained by Klots. Similar numbers of *scudderi* have been compared in Table 2. I was not able to obtain a number of *ruckesi* equal to that used by Klots. New Mexico specimens are scarce in museum collections, and many of those examined were from the original type series. The 14 males represented in Table 2 are from my collection.

Klots also used color to differentiate *ruckesi* from *scudderi* stating: "The ground color of fresh specimens of *ruckesi* is a brighter, more intense yellow than that of *s. scudderi*." Any perceived ground color differences relate to the imperfect manner in which the human eye responds to color. Color can be quantified in terms of spectral wavelength and is designated hue. Two other factors combined in an integrated manner produce the tristimulus quantity chromaticity, which is the basis of color vision. Various combinations of hue, saturation and brightness can produce the same psychophysical response or chromaticity value. Optical reflectance scans were run on the dorsal surfaces of the specimens shown in Figs. 7 and 21. As Fig. 29 demonstrates, the reflectance spectra for these two specimens are identical except for amplitude (intensity). This clearly indicates that both butterflies possess the same ground color or hue. The difference in intensity results from a difference in density of melanic cover scales between the two specimens. The specimen with the larger number of dark cover scales appears a darker yellow to the human eye because of a change in saturation and brightness produced by the dark scales. The spectral response curves show that maximum reflectance occurs at 550 nm, and this is produced by the xanthopterin pigment present in the yellow scales. The absorption in the blue region at 445 nm simply reflects the optical complementary relation that yellow absorbs blue.

TABLE 2  
COMPARISON OF MORPHOMETRIC DATA FOR *Colias scudderi*

scudderi/ruckesi ♂ ♂	ABK <sup>1</sup> (N = 52/45)	CDF <sup>2</sup> (N = 59 <sup>3</sup> /14 <sup>4</sup> )
Average Length of FW (mm)	22.860/22.68	23.350/22.93
Average Width of Border at Cell M <sub>1</sub> of FW (mm)	4.984/5.786	5.203/4.679
Border Width Percentage of Wing Length	21.80%/25.51%	22.28%/20.41%
DFW Cell Black Spot:	ABK	CDF
Present <sup>5</sup>	25 = 48.08%/13 = 28.88%	46 = 77.97%/8 = 57.14%
Trace	20 = 38.46%/10 = 22.22%	9 = 15.25%/4 = 28.57%
Absent	7 = 13.46%/22 = 48.88%	4 = 6.78%/2 = 14.29%

Notes:

1. ABK = A. B. Klots data (1937, p. 324).
2. CDF = C. D. Ferris data.
3. Wyoming specimens collected from 1970-1985.
4. Specimens collected in 1974, 1977, 1980 from geographic region associated with *ruckesi*.
5. Klots divided the DFW spot character into the categories: large, small, trace, absent. Since large and small are subjective, these categories have been combined.

The spectral response curves shown in Fig. 29 represent reflectance relative to a standard photographic white card (90% reflectance) represented by the zero base line. The low-amplitude irregularities in the traces are produced by electrical noise from the photomultiplier tube optical sensor and the digital processing electronics used in the scanning spectrophotometer.

Based upon my study of *C. scudderi* and the data presented in Table 2 and Fig. 29, I do not consider *ruckesi* to be a valid taxon. Thus the specific epithet *scudderi* Reakirt

applies throughout the geographic range of this species.

### BIOLOGICAL NOTES

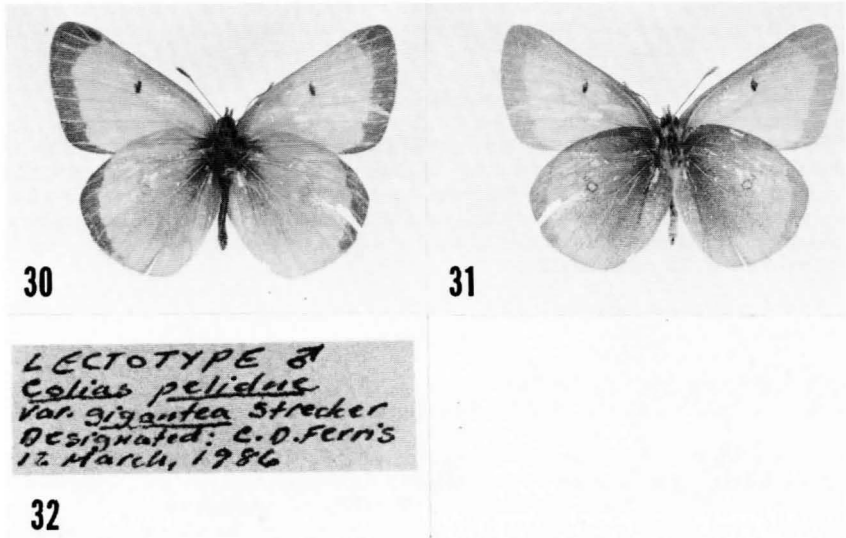
The early stages of *C. scudderi* are only incompletely described. Oviposition in the wild on *Salix* sp. has been reported by W. H. Edwards (1892, 1897), Klots (1937), Ae (1958) and on *Vaccinium* sp. by W. H. Edwards (1892, 1897). Under laboratory conditions, oviposition was obtained on *Salix brachycarpa* Nutt., *S. discolor* Muhl., *Vaccinium myrtillus* [misspelled *myotillus*] L., *Trifolium repens* L., and "weeds" (Ae, 1958). Willow was the preferred substrate. Larvae were reared to the third instar on all three plants, but most of the larvae left the clover upon eclosion. Edwards (1892) reared larvae to the third instar on *Salix babylonica* L., but reported that they would not eat white clover, *T. repens*, (1889). Tietz (1972) cited *Populus* sp. as a larval host, but I have not been able to verify his reference. Willow appears to be the normal larval host with occasional oviposition on *Vaccinium*. It is not known if the larvae can survive to pupation on *Vaccinium*. Scott (1986) has also reported as larval hosts *Salix planifolia* Pursh., *S. lutea* Nutt., and *Vaccinium cespitosum* Michx.

Ae (1958) provided a brief description of the third instar larva. There is one generation annually of this butterfly, and winter hibernation occurs in the third instar. Adults have been recorded from June 27th to September 3rd.

### GEOGRAPHIC DISTRIBUTION

As indicated in the preliminary sections of this paper, *C. scudderi* has a compact distribution encompassing northern New Mexico, central Colorado, NE Utah and SE Wyoming as shown in Fig. 1. It is an alpine species found in willow bogs and along streams at elevations ranging from 9000-11,800' (2745-3600 m).

*Colias gigantea gigantea* Strecker 1900  
Figs. 30-48.



Figures 30-32: Lectotype male of *Colias pelidne* var. *gigantea* [= *C. g. gigantea*]. D (30), V (31) and specimen label (32). LT in FMNH, Chicago.

*Colias pelidne* var. *gigantea* Strecker, 1900: 19. TL — West Coast Hudson Bay, above Fort York. LT — Strecker Coll., Field Museum of Natural History.

= *Colias pelidneides* Staudinger in Staudinger & Rebel, 1901: 15.

= *Eurymus pelidne gigantea* (Strecker); Dyar, 1902: 10.

= *Eurymus christina* f. "gigantea" (Strecker); Barnes & Benjamin, 1926: 8.

= *Colias gigantea* Strecker; McDunnough, 1938: 8.

= *Colias christina mayi* F. & R. Chermock, 1940: 81.

= *Colias gigantea* Strecker; McHenry, 1963: 212.

= *Colias scudderii gigantea* Strecker; dos Passos, 1964: 43.

= *Colias gigantea gigantea* Strecker; Miller & Brown, 1981: 83.

= *Colias gigantea mayi* F. & R. Chermock; Miller & Brown, 1981: 83.

= *Colias gigantea gigantea* Strecker; Hodges *et al.*, 1983: 52.

= *Colias gigantea mayi* F. & R. Chermock; Hodges *et al.*, 1983: 52.

= *Colias scudderii gigantea* [no author]; Scott, 1986: 200.

Strecker failed to designate a type specimen of *gigantea* and I have selected and so labeled a male lectotype from the short series in the Strecker collection. This specimen and its label are shown in Figs. 30-32. As is the case with all of the Strecker material, no locality labels are attached to the specimen pins. Locality information is pinned in the drawers accompanying the scientific name labels. The maximum wing expanse of the LT is 5.0 cm.

Strecker provided only a very brief description of this species: "Differs from the Labrador *Pelidne* in the great size, being from 2 to 2½ inches in expanse, in having very little of the black sprinkling at the base of the wings, in being in the males of a livelier, warmer yellow. There were two yellow females, the others were white with mostly not much indication of the dark borders." Additional characters of *gigantea* are enumerated in Table 1 of this paper and the associated discussion. As noted by Strecker, the females are dimorphic with yellow or white expression. Yellow females dominate in the southern portions of this butterfly's distribution and are gradually replaced by the white phenotype northward. Occasional yellow examples are collected at the northern limits of this species' range, but they are rare, and white is certainly the dominant form.

Two other taxa that I consider synonyms of *C. g. gigantea* are discussed below.

#### *Colias palaeno* var. *pelidneides* Staudinger 1901

TL — "Amer. bor. (Hudson Bay, Alaska)".

HT — Zoologische Museum der Humboldt Universität, Berlin, DDR.

The very brief description of this taxon translated from the Latin reads: "♂ hind wing beneath with central reddish spot as in *pelidne* (a large *pelidne*?)". It appears that Staudinger was confused about not only the correct affiliation of this butterfly but also its type locality. Based upon the punctuation used elsewhere in the publication, he placed Hudson Bay in Alaska. A semicolon would have replaced the comma had he meant to indicate Hudson Bay and Alaska.

#### *Colias christina mayi* F. & R. Chermock 1940

Figs. 45-48.

TL — Riding Mountains, Manitoba.

HT — Male collected 1 July, 1933; in the Canadian National Collection.

In their original description, the Chermocks compared *mayi* to "its nearest relative *gigantea* (Stkr.)", but for some reason placed it in the *alexandra* complex. They stated that *mayi* lacks heavy black overscaling on the HW and costal area of the FW, which they associated with typical *gigantea*. They also stated that the wing fringes of *mayi* are "less intense" [presumed to mean not so pink] than in *gigantea*. In long series, I am unable to separate males of Riding Mts. material from specimens collected at Churchill

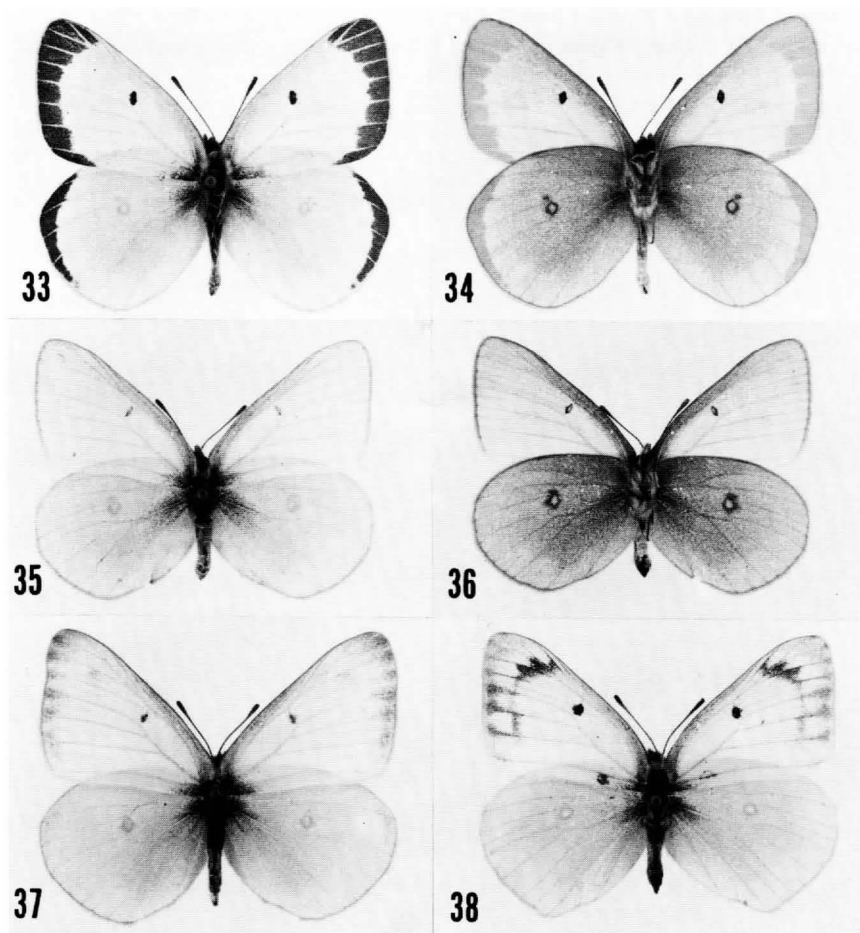
except by examining the locality labels. The only real difference between the southern and northern Manitoba populations is the ratio of white to yellow females. White females predominate at Churchill and yellow ones in the Riding Mts. and at The Pas. Some of the females in southern Manitoba are of very large size, but this is attributed to a milder climate than occurs along the shores of Hudson Bay.

*Colias christina mayi* f. "marjorie" F. & R. Chermock 1940

TL — Riding Mountains, Manitoba.

HT — Female collected 26 June, 1933; in the Canadian National Collection.

This is an infrasubspecific name applied to the white female phenotype of *gigantea* and has no standing according to the Code.

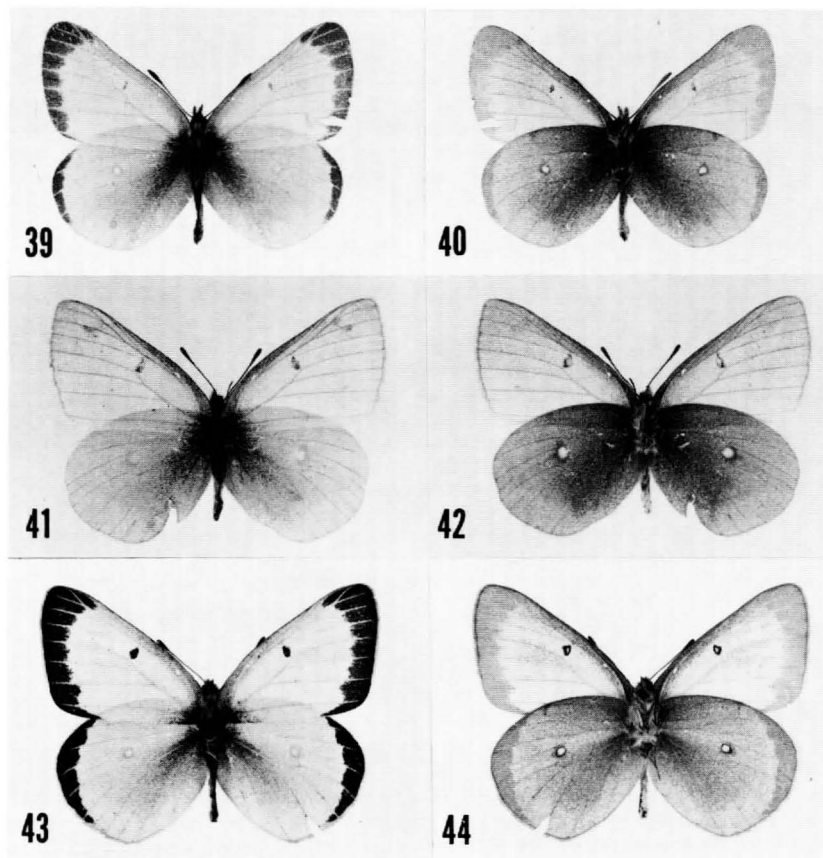


Figures 33-38: Typical specimens of *C. g. gigantea* from Churchill, Manitoba. ♂ D (33), V (34), 14.vii.73; white ♀ D (35), V (36), 15.vii.73; white ♀ D (37), 15.vii.73; strongly marked white ♀ D (38), 12.vii.73. C. D. Ferris Coll.

Masters (1970) commented on the various races of *gigantea* and illustrated the allotype female of *mayi* and a paratype of f. "marjorie". He asserted that *mayi* is distinct from *gigantea* based upon its larger size, the wing fringe color noted by the Chermocks, and reduced melanic overscaling of the HW: "fuscous dusting on the underside of the hindwings of both sexes is very dark in *gigantea* and much sparser in both *mayi* and *harroweri*." If one examines long series of southern and northern Manitoba specimens, all three of these characters break down. I have in my collection specimens from Churchill [the general vicinity of the TL of *gigantea*] that are equally as large as southern Manitoba specimens, and paler ventrally than southern material. Environmental factors appear to play an important role in the determination of phenotype. About all that can be stated is that on the average, specimens of *g. gigantea* from the southern portion of its range are larger than specimens from the northern portion, and that yellow females predominate in the south yielding to white females in the north. I can find no sound basis for considering *mayi* to be a valid subspecies.

\* \* \*

As is the case in most other species of *Colias*, extreme narrow-bordered forms occur. Such an example of *C. g. gigantea* is shown in Fig. 49.

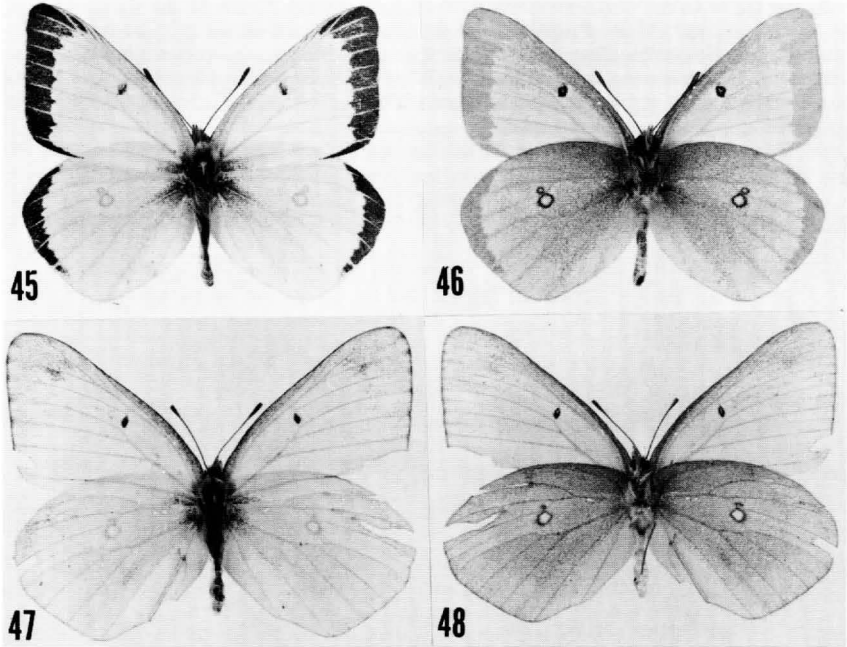


Figures 39-44: *C. g. gigantea*. ♂ D (39), V (40), km 155 Dempster Hwy., Y.T., Can., 12-14.vii.84; white ♀ D (41), V (42), same data as ♂; ♂ (43), V (44), Glacier Rd. at Balto Ck., Seward Pen., AK, 5.vii.86. C. D. Ferris Coll.



*Colias gigantea harroweri* Klots 1940  
Figs. 50-55.

*Colias gigantea harroweri* Klots, 1940: 4-6. TL — Clear Creek, vic. Lower Green River Lake, Sublette Co., Wyoming, 8400'. HT — American Museum of Natural History. HT illustrated by Howe (1975, pl. 97, f. 20).  
= *Colias scudderii harroweri* Klots; dos Passos, 1964: 43.  
= *Colias gigantea harroweri* Klots; Miller & Brown, 1981: 83.



Figures 45-48: *C. g. mayi* [= *C. g. gigantea*] from The Pas, Manitoba, Can. ♂ D (45), V (46), 19.vii.70; ♀ D (47), V (48), 19.vii.73. C. D. Ferris Coll.

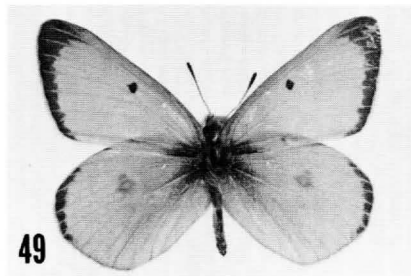
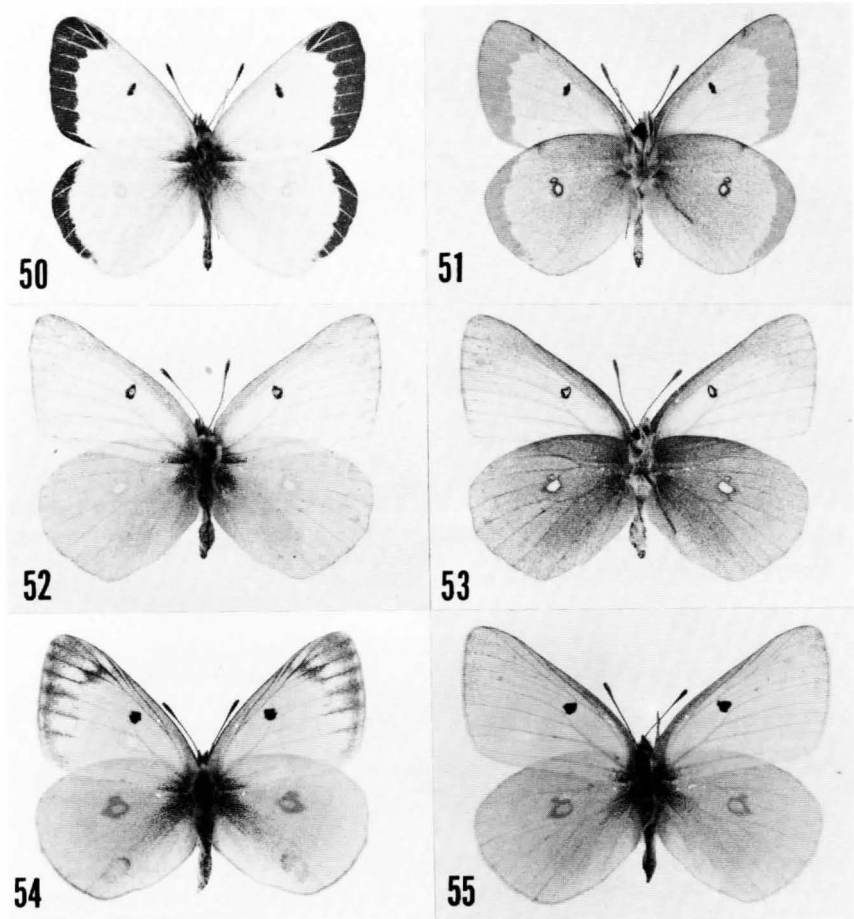


Figure 49: *C. g. gigantea* narrow border ♂ from mi. 506.5 Hudson Bay R.R., Manitoba, Can., no date. Specimen in AME/FSM Coll.

= *Colias gigantea harroweri* Klots; Hodges *et al.*, 1983: 52.

Klots adequately described this subspecies and how it differs from nominate *gigantea*. The principal differences that I have noted are habitat (as discussed in the concluding summary to the *gigantea-scudderi* separation section of the present paper), size, and female ground color. Size data are summarized in Table 3. This subspecies is locally distributed south of the Canadian border and is restricted to transition-zone montane and cismontane willow bogs. Adults are generally smaller in size than those of other *gigantea* populations, excepting those in the northern arctic toward the northern limits of the species' range. The dorsal ground color of the females is often orange-flushed in fresh specimens, particularly in the yellow phenotype. White specimens are creamy-white rather than dead white as in the nominate subspecies. The DHW discal spot is pronounced and bright orange, while it tends to be subdued and often whitish or pale pink in females of *g. gigantea*.



Figures 50-55: *C. g. harroweri*. Topotypes from vic. Slide Ck. Falls, Bridger Wild., Sublette Co., WY, 28.vii.70 ♂ D (50), V (51); white ♀ D (52), V (53) yellow ♀ D (54); Yellow ♀ D, Canyon Ck., Shoshone N.F., Fremont Co., WY, 1.viii.71. C. D. Ferris Coll.

In my experience with Wyoming colonies, the white and yellow female phenotypes occur in about equal numbers. The females tend to be sedentary and must be flushed from the shrub willows during most of the day. Early in the morning, they may be observed nectaring at flowers growing at edges of bogs.

TABLE 3

MORPHOMETRIC DATA COMPARING *C. g. gigantea*, *C. g. harroweri* AND *C. scudderi*

L = horizontal wing length measured along vein  $Cu_2$ , (mm).

B = wing breadth measured through  $R_4-R_5$  fork from costal margin perpendicular to inner margin, (mm).

	♂ ♂				♀ ♀			
	N	$L_{av}$	$B_{av}$	$R_{av}^*$	N	$L_{av}$	$B_{av}$	$R_{av}^*$
<i>C. g. gigantea</i>	21	21.67	16.17	1.34	13	22.87	16.73	1.38
<i>C. g. harroweri</i>	13	20.69	15.23	1.36	13	22.42	16.27	1.38
<i>C. scudderi</i>	25	18.58	14.99	1.24	25	18.58	14.99	1.29

\*  $R = L/B$  ratio as computed from individual ratios and not from  $L_{av}/B_{av}$ .

## DISCUSSION OF TABLE

The specimens used to compile this table are the same as used in Table 1.\* In Table 3, *C. g. gigantea* and *C. g. harroweri* are broken out separately. All data are rounded off to two significant figures. Because of the relatively small numbers of data points, no statistical analysis is provided (standard deviations, coefficients of variation, or t-test). Note above that the  $R_{av}$  values for both sexes and both subspecies of *gigantea* are internally consistent. This indicates that they are in fact conspecific and separate from *scudderi*. For *C. gigantea* taken as a whole, the  $R_{av}$  values (to two significant figures) are: ♂ ♂ 1.35; ♀ ♀ 1.38; as compared to *scudderi*: ♂ ♂ 1.24; ♀ ♀ 1.29. These value differences between the two species are statistically significant as shown by the t-test analysis provided in the discussion of Table 1. As noted immediately above, the  $L_{av}$  and  $B_{av}$  values are smaller for *harroweri* as compared to the nominate subspecies. As would be expected for subspecies (of the same species), the  $R_{av}$  values are comparable.

\*With additional specimens of *C. g. harroweri*.

## Oregon Population

Figs. 56-61.

An isolated population of *gigantea* occurs in the Ochoco Mts. in Crook Co., Oregon. It was noted by Ehrlich & Ehrlich (1961) and Scott (1986, map), but omitted by Dornfeld (1980). I have not visited the locality to collect specimens. Based upon museum material that I have examined and specimens sent to me by several collectors, it has been confused with both *C. alexandra* and *C. occidentalis* Scudder with which it flies.

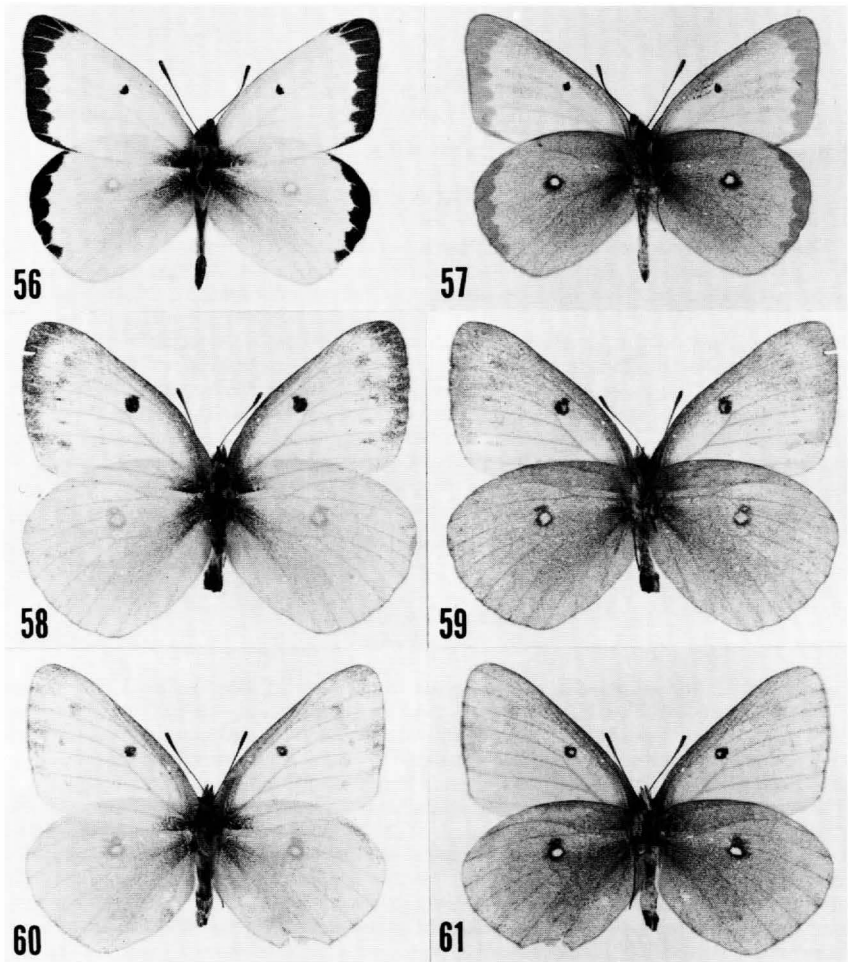
In phenotype, it is somewhat intermediate between *harroweri* and nominate *gigantea*. Physically the specimens are large and all of the females that I have seen (including 20 in my personal collection) are various shades of pale yellow. Males are easily separated from *alexandra* by using UV photography. Neither *scudderi* nor *gigantea* are UV reflective, while *alexandra* males strongly reflect UV light from the HW. Separation of the males from those of *occidentalis* is more difficult. In *gigantea* the following features are generally more pronounced: DFW black cell-end spot, yellow scaling of the wing veins in the black borders, large and frequently double VHW discal spot (as shown for the females in Figs. 58 and 60).

The origin of the Oregon colony is unclear. It perhaps represents the last vestige of a more extensive distribution of *gigantea* in the western United States. Apparently a colony

once existed at Genesee in Latah Co., Idaho, but has since disappeared, a victim of agricultural expansion and habitat destruction. Other species formerly recorded from this area of Idaho and contiguous Washington are no longer found for the same reason. Possibly *gigantea* was once widely distributed from Wyoming to Oregon and northward, but now exists only in isolated montane colonies because of climatic changes and agricultural expansion.

#### BIOLOGICAL NOTES

Klots (in Howe, 1975, p. 365) noted oviposition on *Salix reticulata* L. at Churchill, Manitoba with larval feeding until the third instar in August. It is presumed that hibernial



Figures 56-61: *C. gigantea* Crook Co., OR population. ♂ D (56), V (57), Canyon Ck. Rd., 29.vii.78; ♀♀ D (58, 60), V (59, 61), Hwy. 26 nr. Summit, Ochoco Mts., 26.vii.76. C. D. Ferris Coll.

diapause occurs in the third instar. Klots (1940) reported oviposition on a shrubby *Salix* by the allotype female of *harroweri*. Adults of the nominate subspecies have been recorded from June 18th to August 9th; those of *harroweri* from July 8th into the second week of August.

In the K. W. Philip collection, there are 9 ♂♂ and 2 ♀♀ of a small *gigantea* phenotype that approach *scudderi* in aspect. They were collected in Alaska at Sagwon and the Itkillik River E. of Outpost Mt. Perhaps local environmental conditions are responsible for their appearance.

### GEOGRAPHIC DISTRIBUTION

As indicated in the preliminary sections of this paper, *C. gigantea* has a somewhat disjunct distribution. Its metropolis is north of the Canadian border in western Canada and Alaska (Fig. 2). *C. g. harroweri* has a fairly tight distribution in NW Wyoming, western Montana and south-central Idaho. An isolated colony of an intermediate phenotype occurs in Oregon. Undoubtedly this species is more widely distributed in northern Canada and Alaska than indicated by Fig. 2. Collecting in these regions has been limited by transportation considerations. The species was unknown in the Seward Peninsula until 1986 when I and J. Troubridge each collected a single specimen.

### CONCLUSION

Based upon this study and the data presented above, it is concluded that *C. scudderi* are *C. gigantea* are separate species. They represent the *Salix*-feeding branch of genus *Colias* in North America. Ectopic feeding on willows by larvae of other species has been reported including *behrii* W. H. Edwards (Scott, 1986), *hecla* (E. M. Pike, *in litt.*), and *nastes* (Edwards, 1892). This situation will be addressed in a subsequent paper in this series.

A synonymy is shown below:

- Colias scudderi* Reakirt, 1865
- = *ruckesi* Klots, 1937
- = ♀ f. "flavotincta" Cockerell, 1901
- Colias gigantea* Strecker, 1900
- g. gigantea* Strecker, 1900
- = *pelidneides* Staudinger, 1901
- = *mayi* F. & R. Chermock, 1940
- = ♀ f. "marjorie" F. & R. Chermock, 1940
- g. harroweri* Klots, 1940

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As always, special thanks are due Lee and Jackie Miller for making possible publication of this paper, tactical support in the form of photographic assistance, and for their many kindnesses during my visits to the Allyn Museum of Entomology/Florida State Museum and while a guest in their home.

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The manuscript was reviewed by Drs. J. C. Burne and J. E. Lloyd of the Department of Entomology, University of Wyoming, and their helpful comments are appreciated.

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## COLLECTION RECORDS AND MATERIAL STUDIED

To conserve space, names of collectors and dates of collection are generally omitted. End points of flight periods are indicated. In addition to material in the author's collection, specimens from the following collections were examined: Allyn Museum of Entomology/Florida State Museum; Canadian National Collection; Nelson S. Curtis; J. D. Eff; J. S. Nordin; K. W. Philip. Records were also gleaned from the season summaries published in the *NEWS* of the Lepidopterists' Society. Most, but not, all of the specimens cited in these entries have been examined. Actual numbers examined are shown in ( ).

*Colias scudderi* (285 specimens). Records for Colorado are so extensive that only counties are indicated. This species is widely distributed in willow bogs from approximately 9000' (2745 m) to approximately 11,800' (3600 m) in Colorado. The upper altitudinal level in Wyoming is approximately 10,800' (3300 m). Flight Period: 27.vi-3.ix depending upon season; typical flight period is early vii (south) to early viii (north). COLORADO. County Records: Boulder; Chaffee; Clear Creek; Conejos; Costilla; Custer; Delta; Dolores; Douglas; Eagle; El Paso; Garfield; Gilpin; Grand; Gunnison; Hinsdale; Huerfano; Jackson; Jefferson; La Plata; Lake; Larimer; Mesa; Mineral; Montrose; Ouray; Park; Pitkin; Rio Blanco; Rio Grande; Routt; Saguache; San Juan; San Miguel; Summit; Teller. NEW MEXICO. San Miguel Co.: Summit of range between the Pecos and Sapello rivers, near the headwaters of the Pecos 8000-11,000'; Winsor Ck. Canyon NW of Cowles. Santa Fe Co.: Santa Fe Ski Area. Taos Co.: Head of Cabresto Canyon. UTAH. Daggett Co.: Duchesne Co. Summit Co.: Bald Mt.; Hwy. 150 nr. Lilly L.; Kamal (*sic*, assumed to be Kamas); N. Fk. Provo R.; Yellow Pine. Uintah Co.: N. Fk. Ashley Ck. WYOMING. Albany Co.: Widely distributed in willow bogs above 9000' in the Medicine Bow Range (Snowy Range); common in bogs and along creeks in the vicinity of Brooklyn L., Lewis L., and Libby L., south to Keystone and Foxpark. Carbon Co.: S.R. 70 mi. 40-49; French Ck. area along Hwy. 130 W. side Snowy Range. Converse Co.: La Bonte Canyon.

*Colias gigantea* (1201 specimens). Flight Period: 18.vi-9.viii depending upon season, altitude and latitude; early in the far north and at low elevation, mid-to-late vii in the Rocky Mts. (typical). *Colias gigantea gigantea*. ALASKA. Alaska Range: 6-11 mi. SW Farewell. Brooks Range: Nuturwik Ck. Dalton Hwy.; Canning R. headwaters. Interior: Arctic Village; vic. of Central (Circle, Circle Hot Spgs., Upper Birch Ck.); Charley/Kandik Rivers; Chicken; Delta Jct.; vic. Fairbanks (Goldstream Valley; Tanana R. flats; Palmer Hwy. at Alder Ck.); Kathul Mt.; Nenana; Ramparts; Ray Mts.; Richardson Hwy., mi. 332; Sheenjek R.; Tetlin/Tanacross; Wiseman. North Slope: Itkillik R. (SE Umiat); Sagwon; Umiat. Northwest: Noatak R. valley. Seward Peninsula: Balto Ck. 64°38'N, 165°27.5'W; Omilak R. 65°±01'N, 162°41'04'W. Southcentral: Glenn Hwy. (mi. 14.6, Sheep Mt. area mi. 113-121); Glennallen; Gulkana R. (10 mi. above W. Fk.); Palmer; Richardson Hwy. (mi. 87, Willow L., mi. 95). ALBERTA. Beaverlodge; Blackfalds; Bluesky; Calgary (head of Pine Ck.); Edmonton; Grimshaw (and 5 mi. N.); Hythe (14 mi. W.); Lake Louise (5 mi. E.); Lacombe; Nigel Ck. Trail (Banff N.P.); Peace R. Valley; Red Deer R.; Sexsmith; btwn. Sexsmith and Grand Prairie; Wilcox Pass. BRITISH COLUMBIA. Alaska Hwy. (mi. 29, 30, 106, 115, 146, 149, 170, 220, 258, 275, 337, 356, 392 at Summit L., 399, 415, 515); Atlin (3 mi. N.); Canim L.; Jesmond; Rolla; 100 Mile House. MANITOBA. Churchill; Ft. Churchill; Gillam; Hwy. 304 (E. side L. Winnipeg btwn. 50°N and 51°N); H.B.R.R. (mi. 200, 240, 322, 506.5); Kelsey Dam; Mafeking (5 mi. N.); The Pas (and 20 mi. N.); Pine River; Porcupine Mts.; Riding Mts.; York Factory (N. of). NORTHWEST TERRITORIES. Aklavik; Anderson R. delta; Fitzgerald (nr. Ft. Smith); Ft. Franklin; Ft. Simpson; Ft. Smith; Godlin Lakes; Hay River; Norman Wells; Providence River (20 mi. NE); Reindeer Depot (Mackenzie delta); Salt River (20 mi. N. Ft. Smith); Yellowknife (and 20 mi. N.). ONTARIO. Cape Henrietta Maria; Ft. Albany; Ft. Severn. SASKATCHEWAN. Cypress Hills; Duck Mt. Park; Harlan; Hudson's Bay Jct. (5 mi. E.); Loon Lake; Nipewan [*sic*] Prov. For.; Qu'Appelle; Somme; Spiritwood; Torch River; Waskesiu Lake. YUKON TERRITORY. Alaska Hwy. (mi. 798, 900, 995.2 [Aishihik Rd.], 1127, 1180, nr. Johnson's Crossing). British Mts.: Firth River at Sheep Ck., 69°27'N, 40°25'W. Ogilvie Mts.: Windy Pass, km 155 Dempster Hwy. Richardson Mts.: km 465-468 Dempster Hwy. Kluane Area:



Burwash Ck. Rd.; Bear Ck.; Mt. Decoeli. Dawson; Dawson-Mayo Hwy. mi 34.9; 3 mi. N. of fork of Klondike Rd.; Haines Jct.; Keno-Mayo area; La Force L., 62°41'N, 132°20'W; Old Crow; Rampart House; Whitehorse. *Colias gigantea harroweri*. IDAHO. Latah Co.: Genesee (an old record with no additional data; area now totally devoted to agriculture with no habitat remaining for this species). Blaine Co.: Alturas L. (8-24.vii, J. D. Eff); Alturas Mt. (27.vii.44, CNC). Lemhi Co.: S. R. 29, 8.5 mi. E. Leadore (N. S. Curtis, 18.vii.79). MONTANA. Flathead Co.: (an old record; no additional data). Gallatin Co.: 2.vii.31 (F. M. Brown; no additional data). Glacier Co.: 2 mi. S. Port of Chief Mt. Lake Co.: Swan River State For. Missoula Co.: Seeley L. Park Co.: Shields River Rd. 6000'. WYOMING. Fremont Co.: Canyon Ck., 9100'; Sinks Canyon. Johnson Co.: Cloud Peak Wilderness Area: Soldier Park, 8600'; Seven Brothers Lake area, 8800'. Park Co.: Old Dead Indian Rd. Sunlight Basin area; Swamp L. bog S. side Hwy. 296 11.2 mi. SE jct. Hwy. 212. Sublette Co.: Clear Ck. Trail nr. Slide Falls; Green River Lakes Rd. Teton Co.: Grand Teton N.P.: Fisherman's Landing. *Colias gigantea cline*. OREGON. Crook Co.: Ochoco Mts.: Canyon Ck. Can., Hwy., 26 nr. summit; E. and W. divide on Canyon Ck. Rd.

General distribution records for the range maps were taken from Hovanitz (1950), Opler & Krizek (1984), Riotte (1962) and Stanford (1985).

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