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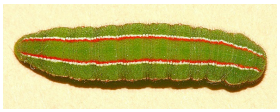

The Taxonomic Report
OF THE INTERNATIONAL LEPIDOPTERA SURVEY

Natural Life Histories of Alaska *Colias* (Lepidoptera: Pieridae)

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Abstract: Eight species of the genus *Colias* of Alaska were studied during the years of 2005, 2006, and 2007. Natural life histories were determined, immature stages described, measured, and photographed. Scanning Electron Microscope (SEM) pictures of the micropyle of five species are included.

Additional key words: *boothii*, *thula*, *gigantea*, *inupiat*, *hecla*, *glacialis*, *nastes*, *aliaska*, *palaeno*, *chippewa*, *philodice*, *vitabunda*, *pelidne*, *canadensis*, *christina*, *kluanensis*, eggs, larvae, pupae, tundra, legume, berm

Introduction

The primary purpose of this research project was to determine the life histories of the 6 species of *Colias* known from the north slope of Alaska. The species studied are *C. boothii thula* Hovanitz, *C. gigantea inupiat* Harry, *C. hecla glacialis* M'Lachlan, *C. nastes aliaska* Bang-Haas, *C. palaeno chippewa* W. H. Edwards, and *C. philodice vitabunda* Hovanitz. This study also included four species of *Colias* from the interior of Alaska. These species studied are *canadensis* Ferris, *christina kluanensis* Ferris, *g. gigantea* Strecker, *philodice vitabunda* Hovanitz. The newly discovered *C. pelidne* Boisduval and Leconte on the north slope is also mentioned.

The north slope is the drainage from the Brooks Range to the Arctic Ocean. All of the north slope is well north of the Arctic Circle and is all tundra. The study was done along the Dalton Highway and along the Trans-Alaska Pipeline at a site 92 miles (147 km) south of Deadhorse (Prudhoe Bay). The study sites are given with each species. Because of the remoteness of the site it was necessary to camp nearby. Fortunately there is a campsite in a lovely flower-covered meadow just far enough from the highway to avoid the dust from the highway and adjacent to the Sagavanirktok River. The mosquitos and no-see-ums (biting flies) also like this meadow. A tent camp was established each year at this site. The project was started in June of 2005 and at that time it was estimated to take two years. The campsite was occupied in 2005 from June 24 to August 13, in 2006 from May 20 to July 13, and in 2007 from June 1 to July 1. By July 1 of 2007 the research was completed, so all stations were abandoned and all material retrieved.

The study area can also be described as Mile 320.5 to Mile 324.5 Dalton Hwy. There is an access road to the pipeline at the south end of the study area and another at the north end of the study area. Larvae stations were established along the pipeline at both of these access roads and also along the pipeline at a point approximately midway between the north and south study sites. The south site is located at 68°57.17'N and 148°52.49'W, and the north site is located at 69°00.61'N and 148°49.42'W at an elevation of 366 meters. This area is a flat river bottom about 3 meters higher than the river. The pipeline is raised about one meter above ground and there is a gravel berm beneath the pipeline. The legumes that some of the *Colias* use grow in abundance on this berm. They also use the legumes in the natural habitat. The berm also provides nectar sources and access to the non-legume feeders. The pipeline also provides considerable safety from the tourists. Because considerable time would be spent establishing and tending the stations, permission to use the pipeline right-of-way was obtained from Alyeska Pipeline Co. at Pump Station 3.

There was a female grizzly bear that lived near the campsite, thus slightly complicating fieldwork. In 2005 she had two new cubs and in 2006 they were still with her and just about as large as their mother. They were

occasionally observed foraging in the area. The female was known by regular caribou hunters as being very good about leaving people alone. The first day in camp in 2006 they came into camp to welcome me back. When they were discovered in camp they were only 20 feet away. When the mother observed me she just took a quick curious look and then began to wander away. Since she is so non-threatening it was probably good to have her in the area, as she probably kept the males away while she had the cubs. She was not observed in 2007.

Climate and Weather

The weather information herein is mostly temperature data, but a few remarks are made about precipitation. While in camp the daily high and low temperatures were recorded with my own thermometer. Naturally, some days the exact high or low temperatures were missed, but the temperature that was obtained would be a good representation for that day. Also at the campsite is a U.S.G.S. gauging station with a thermometer. Temperature data was obtained for the years previous to the study, 1997 to 2004. Temperature data prior to 1997 and for the year 2000 was not available. Dan Bartu with the U.S.G.S. in Fairbanks obtained the data. Seven years of data is not sufficient to establish an accurate daily average, but it does at least provide some idea of the normal temperature. Temperature data was also obtained for May and June of 2005 and the last half of August when the camp was not occupied. The U.S.G.S. thermometer was acting erratically in 2006 so temperature data for the last half of July and all of August was not obtained. A synopsis of the temperatures is given in Table 1 (page 15).

The spring and summer of 2005 were very dry. It appeared obvious that conditions were dry upon arrival at the campsite in June of 2005. Also, comments from Alyeska personnel indicated the spring had been dry. From June 25 to 29 of 2005 the weather was very warm (24-26°C) and sunny. Then on June 30 a north wind of 8-12 kts started and continued until August 2. This wind caused July to be unusually cold. The first 20 days of July were 3.6°C below average. The last ten days of July were nearly normal, then the first half of August was pleasant. Very little rain occurred during July and August.

In 2006 the temperature from 21 May to 13 July was quite normal. When I arrived at the campsite on May 20 of 2006 the snow had just melted from the flat areas. There were still minor snowdrifts beside the pipeline, etc. There was occasional snowfall until June 9. Thereafter there was much rain and limited sunshine until July 9. During the first half of July the mountains to the south (Brooks Range) were almost constantly cloud covered and there was much rain.

In 2007 the first ten days of June were sunny and exceptionally warm. During that ten-day period the daily high temperature averaged an incredible 10.1°C above average. After that there was a spell of three cool days then the weather was warm for the rest of June.

By comparison, in 1971 there was a cold spell around the first of July that lasted for a couple of days. In 1991 there was no cold spell from June 21 to July 15, and there were only two non-collecting days during that period. The primary flight and egg maturing time frame for *Colias* is June 20 through July. It is common that there is a cold spell (even with snow) during this period but the spells normally last only two or three days then the temperature returns to normal. The first 20 days of July 2005 were exceptionally cold which delayed egg development and caused many to die.

Eggs and Plants

In 1991 and 1999 there was an extremely good butterfly flight (all species) in the research area and in the Franklin Bluffs area. The Franklin Bluffs construction camp site was at Mile 378 Dalton Hwy, which is 37 miles (59 km) south of Deadhorse and on the coastal plain. From 2000 to 2003 the butterfly flight was moderate to poor. In 2005 and 2006 the butterfly flight at the study site was extremely poor. Except for *Boloria frigga, Colias*, and the blues there were almost no butterflies and these taxa were very few. It is incredible that the butterfly population could be so depauperate. In 2005 there were a few individuals flying as late as August 5 (including *C. philodice* and *C. gigantea*), this was probably because of the cool weather in July. In 2005 the flight at Franklin Bluffs was poor (*C. hecla* was still flying on August 10) and in 2006 it was moderate, except that *Colias boothii* had an abundant flight. At the research site in 2005 there was just barely enough *Colias* to be able to start the research project, except *boothii* of which only one female was obtained. Because of the extremely warm first ten days of June in 2007 the flight of most species was very early. However, the *Colias* flight was only a few days early. There was an extremely abundant flight of all Satyrids and *B. frigga*. By June 24 there were only a few of these still flying and most of them were worn. The abundance of other taxa was still low.

We always wonder why a particular year had a poor flight, yet another year an abundant flight. Sometimes it seems obvious that weather had been a major factor, either positive or negative. Sometimes predators or parasites

seem abundant, for example, Ken Philip (pers. comm.) has observed an abundant amount of wasps during a particular year and accurately predicted a poor butterfly flight for the following year.

Short cold spells of two or three days on the north slope during July are common, so these probably have no affect on butterflies. Extended cold spells, such as during 2005, do have an adverse affect, when many eggs did not hatch. At the study sites in 2005-2007 there was an abundance of spiders. The majority of these were wolf spiders, but there were some other types as well. These "wolfies" were especially noticeable to the researcher who was paying extra attention to the ground and plants. Even more attention was paid to the larval stations and immediate area around each station. Quite commonly there were spiders on, or associated with the stations. Considering that spiders like to eat larvae, it was disgusting to observe so many spiders when trying to conduct research. It is not known if this abundance of spiders is normal, therefore it is impossible to ascertain if they have had an extra adverse affect in recent years. Some wasps, both small and large, were observed during the study period, 2005-2007. There did not seem to be an unusual abundance so they probably had no more than the usual affect. Interestingly, a few (four or five) larvae under the sleeves were parasitized by Ichneumonidae wasps. They were probably stung while resting on the sleeve. Little birds have been commonly observed in the area, but no extra abundance was observed during the study period.

I had hoped to obtain an accurate determination of how long it takes the eggs to hatch in nature. In 2005 many ova were deposited during the last few days of June. After 10 days the ova were monitored every 2 or 3 days. The majority of these ova did not hatch because the temperature remained unusually cold until July 20. All of the eggs turned orange, so they were fertile. The ova that did hatch took 3 to 4 weeks. On July 9 a *hecla* ovum was observed being oviposited on a plant that was growing in bare gravel. This was a warmer microhabitat than for most of the ova, so this ovum took only 2.5 weeks to hatch. Throughout the month of July, many more ova were obtained. By the amount of larvae found the next spring it appears that most of these later ova hatched.

In 2006 some *boothii* eggs that were laid on June 25 began hatching on July 11, so these eggs took 18 days to hatch. The temperature during this period was fairly normal yet a little below normal during the first 10 days of July. The 18 days these eggs took to hatch is probably quite normal. During a year when there is no cold spell during this period the eggs could conceivably hatch sooner.

It was assumed that the first instar could be observed and there would be evidence of eating. However, this did not turn out to be the scenario. Very few pre-diapause first instar larvae of *hecla* and *nastes* were observed. Therefore it was uncertain whether there were very many. As it turned out most of them did very little noticeable eating before diapausing, however, there were exceptions. It was considered unwise to poke around in the litter and moss at the base of the plants to search for larvae in diapause since they could easily be injured. In the spring when the post-diapause larvae came out of hiding to start eating on the newly growing plant they could be observed. Since many can still be missed, it was never certain how many there were. This is also true for the second, third, and fourth instars since there was no need to poke around the plants. The number of larvae observed would vary from time to time. The number of larvae was never reliably obtained, but this did not matter since the primary purpose was to observe the larvae maturing into adults.

As stated above, the legumes that the *Colias* use grow in abundance along the pipeline berm. These legumes also grow commonly in natural habitat from this study site north to The Franklin Bluffs area. At the research site the legume feeding *Colias* fly more abundantly along the pipeline than in the natural habitat. This may be because there are more nectar source flowers along the berm. In the Franklin Bluffs area the *Colias* fly in the natural habitat as commonly as along the pipeline. The brushy *Salix* species that *gigantea* use grow abundantly along the pipeline berm, and in wet and semi-wet areas along side the pipeline, and in many other areas. *C. gigantea* females were observed ovipositing on *Salix* in wet areas but were never observed ovipositing (or even interested) on *Salix* along the pipeline berm. The *Vaccinium* plants that *C. palaeno* uses grow abundantly in semi-wet areas beside the pipeline and in natural areas from the research site to Franklin Bluffs. *C. gigantea* are rather difficult to catch in their natural habitat. Nectar sources (primarily yellow composites) for this species grow abundantly along the pipeline. Therefore, the pipeline provides both nectar sources and access through the preferred habitat for *gigantea*. The pipeline also provides habitat and/or nectar sources for all of the other butterflies that live in the area. The tent also provided a popular meeting place for a couple species of microlepidoptera.

Most of the plant species on the north slope start to dessicate for winter in early August. The *Arctostaphylos alpina* L. is bright red during the first half of August. By the middle of August most of the plants that the *Colias* use are changing color and apparently partially dessicated. Some individual plants of all the species that *Colias* use are still edible at the end of August. A few larvae were observed eating on August 30, these are noted with the species.

On May 23 and 24 of 2006 a few of the legume plants had already started to grow. As soon as there was growth the larvae started eating. At two stations there were too many larvae so the new growth was entirely eaten, so the larvae had to be moved to another plant. Some plants did not grow at all, so the larvae there had to be moved to a growing plant. The *Vaccinium* and *Salix* are the last to start growing leaves. In 2006 the *Salix* did not start to grow leaves until June 10, and many of the *Vaccinium* plants had buds starting to swell on June 5.

Larval Behavior

Colias larvae almost entirely eat the leaves of the hostplants. Rarely one was observed eating the buds or flowers and even then there was very little eating of the buds or flowers. In general, the first through third instar larvae eat the mesophyll of the leaf and leave the membrane and veins. This varies somewhat, especially with the third instars which sometime eat the entire leaf. This also varies with the different plant species and the age of the growth. The fresh growth in the spring is eaten entirely even by the first instars. The mature leaves of *Salix* and *Vaccinium* are the most difficult to eat, so larvae smaller than fourth instar never eat the entire mature leaf.

The most common resting place for the first through third instar larvae is on the upper side of the leaf along the mid-vein. However, this varies considerably in all species. Sometimes they rest on the underside of the leaf, along the petiole, and occasionally along the stem. Fourth and fifth instar larvae that are eating *Hedysarum, Vaccinium*, and *Salix* stay on the plant and rest anywhere, while those eating *Astragalus* and *Oxytropis* like to rest on the ground. These *Colias* larvae overwinter in various instars. The overwintering stages are discussed with each species. There is no evidence anywhere in the world that any *Colias* overwinters as a pupa.

Very soon after the snow has melted the larvae break diapause and become visible while they are waiting for their hostplant to start growing. Some plants started growing very soon while other took a couple of weeks. At a few stations the plant never did grow, which required that the larvae be moved to a new plant. It was quite a nuisance to have to find the first instar larvae so that they could be moved. It was rather amazing how long the first instar larvae remained alive without eating. As time elapsed it became a concern that they would start to die. At three weeks time, without any plant to eat, as many larvae as could be found were moved to a new plant. Every day or two the old site would be visited and sometimes more larvae were found. At 27 days a few larvae were found still alive. Mature fifth instar larvae leave the hostplant and wander about to find a place to pupate. This is usually near the ground on a stem. Those confined under a sleeve would usually pupate on the netting near the ground.

In discussions concerning the elapsed time of development from egg to adult the followng terminology is used. The first summer - this is the summer in which the egg was laid. The second summer is one year of elapsed time from egg. The third summer is two years of elapsed time from egg.

Materials and Methods

Net sleeves were placed over the larval hostplants at numerous stations within the study sites. These sleeves were to sequester the females for ovipositing on the larval hostplant and then left in place to protect the larvae. The netting was green polyester netting that BioQuip Products sells for butterfly nets. The netting was supported by two 9-gauge wires. The wires were bent in U shape so that the sleeves would fit over them, and the ends were pushed into the ground. The two wires were placed at 90° to each other to hold the sleeve in place. The bottom of the sleeve was secured by rocks. The rocks had to be placed touching each other to provide a seal to keep predators out. Since the sleeves (stations) are out in nature they are subject to being damaged or destroyed so several stations were established for each species.

The stations were checked every 2 or 3 days and reset when they had been disturbed. When it became apparent that the ova were about to hatch they would be monitored daily to find out when the ova hatched. Thereafter, the contents would be checked occasionally to monitor the progress of the larvae. In 2005 the sleeves were removed on August 30 for the winter and in 2006 the sleeves were removed on September 8. The sleeves were reset on May 24 in 2006 and on June 2 in 2007. Some of the data of the immature stages was obtained at home during the five years prior to 2005. During this project some of the data was obtained in camp and some at home. The larvae that were reared at home were put on potted plants or on cut stems that were placed in water. The potted plants were covered with net sleeves; the cut stems were placed in a plastic container or a bucket with a netting cover. When the larvae stopped eating and were preparing to molt they would be placed in a separate container (still on the leaf). First they would be measured for length and then left to molt. After molting they would be returned to the hostplant and the molted head capsule would be measured. It is rather difficult in the field to monitor the larvae to see when they are getting ready to molt. However, some of the third instar, all of the fourth and fifth instar larvae of *hecla, nastes*, and

philodice were measured in the field. The first and second instar *nastes* and *palaeno* that were used for measurements were reared in closed plastic containers in camp. *Colias* larvae that are reared in a closed container eventually die (usually third instar), so these were sacrificed.

The larvae were left under the sleeves to pupate. Pupae were collected so that they could be measured. Then the pupae were placed under a sleeve to pupate in natural conditions. Pupae not needed for measurements were put in a communal sleeve near camp for easy monitoring.

Larvae that were reared in the lab were overwintered in the refrigerator. A large plastic container, with the lid on, was used. Four small containers with water for humidity were set in the large container. The larvae were put in small plastic containers that have numerous holes and these containers were put in the large container. No plant material was put in the container with the larvae, since plant material would mold.

Morphological observations and measurements of the eggs, first instar larvae, and all the head capsules were made with the aid of a stereomicroscope and a 0.1 mm scale. Length measurements of the second instar and larger larvae and pupae were made with a mm scale and the aid of 3X reading glasses. Measurements of the head capsule width are of the molted head capsule. Measurements of the length of the larvae were made at pre-molt stage. Length of the fifth instar larvae is given for the mature larva during the most common resting position . Their length during resting varies so this measurement is somewhat nebulous. N=10 for all measurements unless otherwise noted. Pupal width is the width of the pupa from side to side. Pupal height is the back to the outside edge of the wing cases.

General Description of *Colias* Immature Stages

Eggs: Fig. 30. The eggs are typical of the *Colias.* The eggs are fusiform in shape with longitudinal ribs and small transverse ridges. The top is rounded and contains the micropyle. Eggs are creamy white when oviposited and become orange with a creamy tip within 4 or 5 days in the field (2 days in the lab). Prior to hatching the eggs exhibit a black tip, the head of the larvae can be seen through the shell. Eggs hatch in 5 days at room temperature but vary in nature as mentioned above. The size is given under each species.

Larvae: All *Colias* have five larval instars. The first instar larvae are similar and are described here rather than repeating under each species. Any exceptions are given with the species.

First instar: Head is black with tiny white hairs. Body is green with dark green mid-dorsal stripe. On each side of body there are 3 white hairs on each segment except the first segment which has 5 white hairs. The lateral line is cream colored and there is a cream colored ring around the base of the hairs. Occasionally a few larvae have black hairs on the head and a few on the body. There are many black dots on a yellow body under 20X magnification. The spiracles are black, and the thoracic legs are dark green to black. There is a dark area above the anus on the majority of the larvae but not all of them.

Second to fifth instar: These are similar so only the fifth instar is described. The size of each instar is given with each species. The following characters are similar in all species. The head and body are green with many black spots with give rise to black or white hairs. The spiracles are white with a black ring. Sometimes the spiracles exhibit the color of the lower half of the lateral stipe. The dorsal stripe is dark green and the eyes are black. The other features or variations of these features are described with each species.

Pupae: Fig. 31. The pupae of all species are similar so they are described here, exceptions are given with the species. Head is green with front darker green, light green horizontal line in middle. Body is green, lighter green posterior. The dorsal stripe is dark green. The sub-dorsal stripes are light green and faint. The lateral stripes are light green or yellow and faintly expressed on wing cases. The spiracles are light green. The sub-lateral stripe is brown on three segments immediately behind wings, there is a small black spot between lateral stripe and sub-lateral on two segments immediately behind wings. The posterior end of the pupa is attached to a silk pad on the substrate and the body is held loosely to the substrate with a silk girdle.

Species Accounts

Colias boothii thula
at north slope research site
Figs. 1-13, 16, 17, 42

Eggs: Length 1.30 mm (range 1.20 to 1.40), width 0.50 mm (range 0.45 to 0.55).
Larvae:
First instar: Length 3.1 mm (range 2.9 to 3.4), head width 0.35 mm (range 0.33 to 0.36).
Second instar: Length 5.2 mm (range 4.5 to 6.0), head width 0.58 mm (range 0.55 to 0.60).
Third instar: Length 7.5 mm (range 7.0 to 8.6), head width 0.85 mm (range 0.80 to 0.90).
Fourth instar: Length 14.8 mm (range 13.6 to 16.2), head width 1.50 mm (range 1.35 to 1.56).
Fifth instar: The hairs are usually black but white hairs have been observed. Occasionally the dorsal stripe is not apparent. The sub-dorsal stripes are white with red or orange on dorsal side. There is a black patch on lateral side of sub-dorsal stripe on each segment. On some larvae these patches are not present. The lateral stripes are white with red on ventral side. Length 24 mm, head width 2.5 mm (range 2.28 to 2.80).
Pupae: Length 18.2 mm (range 17.0 to 21.0), width 5.0 mm (range 4.5 to 5.5), height 6.4 mm (range 5.5 to 7.0).

Results

C. boothii females have been observed ovipositing on *Hedysarum mackenziei* Richards (Fabaceae), and *Astragulus arcticus* Bunge (Fabaceae). The larvae were reared on *mackenziei* and *arcticus* in nature at the research site. The larvae were reared on a *Thermopsis* sp. (Ken Hansen), *Hedysarum boreale* Nuttall., *Thermopsis montana* Nutt. in T & G. (Fabaceae), and *Astragalus cicer* L. in the lab.

In 2005 only one female was collected (on Jun 25) which oviposited 40 eggs under one sleeve. On July 29 four first instar larvae were put under a second sleeve. On August 29 two second instar larvae were observed in hibernation and a third was observed still eating. They overwintered the first winter as second instar. In early June of 2006 the second station was destroyed by an animal and no larvae were found. On June 10 of 2006 eight larvae were observed, these were second and third instar. On July 10 there were 17 larvae, these were third, fourth, and fifth instar. On September 8, ten fifth instars were located; these were all on the sleeve near the ground. It was apparent that they had tried to wander away to hibernate, so had finished eating. If they had been left there after the sleeve was removed they would not have been found the next spring, so they were taken to the lab. Unfortunately, they all died during the winter. Also, on September 8 six fourth instar larvae were observed. In June of 2007 only one of these was found. This one pupated and became an adult the third summer.

In 2006 many ova were obtained from females collected in the Franklin Bluffs area. On June 2 of 2007 there were a few first instar larvae observed. On June 8 there were second, third, and one fourth instar larvae. This shows that they overwintered as first, second, and third instar. Altogether there were about 150 larvae during June. When camp was abandoned on the first of July, 142 fifth instar and two fourth instar larvae were put in containers to take to the lab. A few of these larvae had already diapaused for hibernation until the next spring. These larvae were shipped by express mail from Fairbanks, Alaska to Salt Lake City, Utah. The next spring 84 of these larvae pupated without eating. Those that did not pupate were dead or died without pupating.

Discussion

The larvae vary in that some have the black patch and some do not. The black patches are present in all of the *hecla* group, including *johanseni* (Harry, 2005), except *canadensis*. The larvae of *boothii* are the only species of the *hecla* group that exhibit the red along the sub-dorsal and lateral stripes. The adult phenotypes vary considerably, especially the males. Some females appear the same as some *nastes* females which is not unusual among *Colias* species.

All of the larvae exhibited a two year life span. The normal behavior is for the larvae to become fully grown sometime during the second summer. Once they become mature fifth instar they diapause, even if they are mature by July 1, until the next spring. They leave the hostplant and wander away to hibernate, and then pupate in the spring without eating.

The larvae that died in the lab were diseased. They probably became diseased during the shipment to Salt Lake City. *Colias* larvae become diseased easily when they have been in a closed container especially when there are many in a container.

Colias gigantea inupiat
at north slope research site
Fig. 22

Eggs: Length 1.42 mm (range 1.22 to 1.56), width 0.55 mm (range 0.49 to 0.61).
Larvae:
First instar: Length 3.1 mm (range 2.7 to 3.2), head width 0.38 mm (range 0.36 to 0.40).
Second instar: Length 5.0 mm (range 4.5 to 5.5), head width 0.56 mm (range 0.50 to 0.65).
Third instar: Length 8.5 mm (range 7.1 to 10.5), head width 0.95 mm (range 0.78 to 1.25).
Fourth instar: Length 14.5 mm (range 13.8 to 15.2) head width 1.5 mm (range 1.46 to 1.65).
Fifth instar: Only black hairs have been observed except that sometimes the hairs are white on the lower half of head and body. The sub-dorsal stripes are yellow and faint. The lateral stripe is white. Length 24mm, head width 2.4 mm (range 2.28 to 2.62).
Pupa: Length 19.7 mm (range 18.5 to 21.0), width 5.0 mm (range 4.5 to 5.5), height 6.3 mm (range 5.5 to 7.0).

Results

C. gigantea females have been observed ovipositing on *Salix lanata* L. (Salicaceae). They probably also use other brushy willows. The larvae were reared on S. *lanata* at the research site. They were reared on *Salix exigua* Nutt. in the lab.

C. gigantea was the last *Colias* to start flying in 2005. This was because none had started flying before the cold spell started on June 30. From July 7 to July15 five females were collected, which did not lay any eggs. Three females were collected on July 21; these laid only four eggs. A few more females and some eggs were obtained in the next few days. The results at the three stations that eventually had larvae are given next.

Station #36: On July 26 and 27 a few eggs were laid. On Aug 28 six larvae were observed. One of these, a second instar, was still eating. In the spring of 2006 this station was submerged and no larvae survived.

Station #37: On July 24 about 12 eggs were laid, these eggs hatched on August 10. No larvae were observed when the sleeve was removed on August 30, they were probably in hibernation in liter at the base of the plant. In the spring of 2006 the station was slightly submerged, but on June18 four larvae (first and second instar) were observed. On July 4 four larvae (one third and 3 fourths were observed. These were left in the sleeve when the camp was abandoned on July 13. That was unfortunate because on September 8 when the sleeve was removed, the plant, ground, and sleeve were covered with dust (from nearby road construction) so no larvae were observed.

Station #38: On August 10 of 2005 there were 12 larvae at this station. On August 30 no larvae were observed so they were in hibernation. On June 14 of 2006 three larvae (second instar) were observed. No larvae were observed on Sept. 8.

During early June of 2007 one fourth instar at Station #37 and one fourth instar at Station #38 were found. Both of these larvae became adults in late June.

On June 28 of 2007 one female was collected and about 70 eggs were obtained. These were reared in the lab under constant light and one became an adult on Aug. 9. All of the other larvae diapaused as fourth instar. During July of 2006 approximately 70 to 100 eggs were obtained in three different sleeves. In 2007 there were no larvae in these three sleeves.

Discussion

This taxon had the poorest results of all of the *Colias* on the north slope. There were 16 known larvae which resulted in only two larvae in 2007. Therefore all of the known larvae completed development the third summer.

Colias hecla glacialis
at north slope research site
Fig. 18

Eggs: Length 1.35 mm (range 1.30 to 1.44), width 0.55 mm (range 0.50 to 0.57).
Larvae:

First instar: Length 3.0 mm (range 2.8 to 3.4), head width 0.35 mm (range 0.31 to 0.38).

Second instar: Length 4.7 mm (range 4.3 to 5.0), head width 0.53mm (range 0.51 to 0.56).

Third instar: Length (N=6) 7.5 mm (range 7.2 to 8.0), head width (N=7) 0.83 mm (range 0.78 to 0.88).

Fourth instar: Length 13.7 mm (range 13.0 to 16.0), head width 1.33 mm (range 1.25 to 1.50).

Fifth instar: Only black hairs have been observed. The sub-dorsal stripes are yellow. There is a black patch on the lateral side of sub-dorsal stripes on each segment. The lateral stripe is white. Length 24 mm, head width 2.3 mm (range 2.18 to 2.48).

Pupae: There are a few faint dark streaks on wing cases. Length 18.3 mm (range 17.0 to 20.0), width 5.0 mm (range 4.5 to 5.5), height 6.0 mm (range 5.2 to 6.2).

Results

Females have been observed ovipositing on *Astragalus arcticus* and *Hedysarum mackenziei*. Many more observations have been on *A. arcticus* than on *H. mackenziei*, so it appears that *Hedysarum* is used only occasionally. The larvae were reared on *arcticus* and *mackenziei* at the research site and *Astragalus cicer* in the lab.

Only four females were collected in June of 2005. These females were put in two stations. Many eggs were oviposited at both stations. During July it appeared that very few, if any, of the eggs hatched. From July 15 to August 2 eight more stations were established for females to oviposit. Some of the females were taken at the research site and some at Franklin Bluffs. The next spring approximately 45 post-diapause larvae were found among all the stations. The plants at five of the stations did not grow. Larvae that could be found at these stations were moved to another station.

On August 29 of 2005 five first instar and two second instar larvae were observed. The first instars were still eating and the second instars were in hibernation. On June 12 of 2006 there were first, second, third, and fourth instar larvae found. The fourth instar may have overwintered as third instar. As late as June 18 some first, second, and third instar larvae were found at a station where the plant did not grow. It is amazing how long the first instar can survive while waiting for some food. On June 24 the first pupae was attained, and on July 11 this pupa emerged. All together there were 7 *hecla* (1m, 6f) that became adults in 2006. At one station on July 4 there were two fourth instar and on July 7 they appeared to have diapaused. During June of 2007 only three larvae were found of the 25 that were known in July of 2006. All three of these larvae became adults in June of 2007.

During early July of 2006 three new stations were established with females for oviposition. There were no eggs at one station but many eggs at the other two stations. On June 8 of 2007 there were two fourth instar and six fifth instar larvae. All of these larvae became adults in June of 2007.

Discussion

Some larvae had definitely overwintered as first, second, and third instar. Most of the first instars would have had plenty of time to attain second instar but apparently they wanted to remain first instars.

Of the larvae started in 2005 seven became adults in 2006 which means that they completed development in one year. All of the larvae (only 3) in 2007 became adults in June. Of the many eggs that were started in 2006 only three resulted in larvae. These three larvae became adults in 2007.

Colias nastes aliaska
at north slope research site
Figs. 21, 43

Egg: Length 1.30 mm (range 1.21 to 1.36), width 0.53 mm (range 0.50 to 0.57).
Larvae:

First instar: (N=6) Length 3.1 mm (range 2.7 to 3.4), head width 0.35 mm (range 0.33 to 0.38).

Second instar: Length 4.5 mm (range 4.0 to 4.8), head width 0.50 mm (range 0.49 to 0.53).

Third instar: Length 7.6 mm (range 6.7 to 9.0), head width 0.82 mm (range 0.75 to 0.90).

Fourth instar: Length 12.4 mm (range 9.5 to 13.8), head width 1.32 mm (range 1.12 to 1.44).

Fifth instar: The description is same as *hecla*. Length 23 mm, head width 2.3 mm (range 2.15 to 2.38).

Pupa: There are a few dark streaks on wing cases. Length 17.3 mm (range 16.0 to 18.0), width 5.0 mm (range 4.8 to 5.0), height 6.0 mm (range 5.8 to 6.5).

Results

Females have been observed ovipositing on *Oxytropis borealis* DC (Fabaceae). There has been no evidence that females have been interested in ovipositing on any other species of plant. Larvae were reared on *Oxytropis borealis* at the research site. In the lab first instar larvae would eat *Thermopsis montana* but did not grow and eventually died, and they would not eat *Astragalus cicer.*

In June of 2005 two stations were established with females for ovipositing. One of these stations was a potted plant. Approximately 30 ova were obtained on the potted plant and 40 to 50 ova at the other station (#15). None of the eggs on the potted plant hatched and only 6 larvae were the most ever observed at #15. More results at this station are discussed because the eggs were laid early and the larvae grew slowly. On August 28 six first instar larvae were observed. On May 23 of 2006, when the sleeve was installed, two first instar larvae were observed and they were apparently eating. On June 8 they were still first instar. On September 8 five third instar larvae were observed. In June of 2007 nine pupae were taken from this station, so there was apparently no loss of larvae at this station.

From July 15 to 25 of 2005 four more stations and one on August 2 were established for females to oviposit. Many eggs were obtained and eventually over 130 larvae. On August 29 five first instar larvae were observed in hibernation. On May 24 of 2006 one third instar larvae was observed which was already eating. On June 13 there were first, second, third, and fourth instar larvae. The first pupa was attained on June 22 and the first adult on July 9. All together there were 10 *nastes* (2m, 8f) that became adults in 2006.

During July of 2006 there were 134 larvae accounted for. During June of 2007 only 23 larvae were accounted for and all of these became adults in June of 2007. In early July of 2006 three new stations were established for ovipositing and many more ova were obtained. In the middle of June of 2007 55 larvae were accounted for. Only four of them did not become an adult in 2007. One of these three stations had no larvae in 2007.

Discussion

A few of the individuals (10) that were started in 2005 completed development in one year. All of the rest (that were found) completed development in two years. Nearly all of the individuals that were started in 2006 completed development in one year.

Colias palaeno chippewa
at north slope research site
Figs. 19, 31, 44, 48, 49

Egg: Length 1.37 mm (range 1.25 to 1.53), width 0.49 mm (range 0.45 to 0.54).

Larvae:

First instar: Length 3.1 mm (range 3.0 to 3.3), head width 0.30 mm (range 0.28 to 0.33).

Second instar: Length 5.0 mm (range 4.1 to 5.5), head width 0.53 mm (range 0.46 to 0.59).

Third instar: (N=4) Length 6.9 mm (range 6.3 to 7.4), head width 0.85 mm (range 0.78 to 0.90).

Fourth instar: Length 12.4 mm (range 11.2 to 13.2). head width 1.22 mm (range 1.13 to 1.31).

Fifth instar: Only black hairs have been observed except that sometimes the hairs are white on lower half of head and body. There are no dorsal or sub-dorsal stripes. The lateral stripes are yellow. Length 23 mm, head width 2.1 mm (2.00 to 2.17).

Pupa: There are no sub-dorsal stripes and the sub-lateral stripes are faint. Length 17.5 mm (range 16.5 to 18.5), width 4.7 mm (range 4.5 to 5.0), height 6.0 mm (range 5.5 to 7.0).

Results

Females have been observed ovipositing on *Vaccinium uliginosum* L. (Ericaceae). The larvae at the research site were reared on *V. uliginosum*. The larvae were reared on *V. caespitosum* Michx. in the lab.

From June 29 to July 21 of 2005 five stations were established for females to oviposit and many eggs were obtained. At one station on August 28 there were some first and second instar larvae still eating. On June 17 of 2006

there were second, third, and one fourth instar larvae. In total there were approximately 110 larvae, so it appears that many *C. palaeno* eggs hatched. This is probably because most of them were laid after the cold spell in July of 2005. On June 22 one fifth instar larvae was observed. This fifth instar became an adult on July 13. Some of the third instar larvae that were observed on June 17 diapaused without becoming fourth instar.

During July of 2006 there were 130 larvae accounted for. In June of 2007 there were 47 larvae accounted for and all of these became adults in June of 2007.

On July 9 of 2006 one station was established for females to oviposit and about 30 eggs were obtained. In June of 2007 only one larvae was found which became an adult on June 23.

Discussion

In 2006 one individual completed development in one year. The rest completed development in two years. In 2007 one individual completed development in one year, this one represented all of those that were started in 2006.

Colias pelidne
at north slope research site
Figs. 20, 50-55

In June of 2007 one female was collected on June 28 and one female was collected on June 29. This was only a few days before the research concluded so it was impossible to conduct life history research. The females would not oviposit on *Salix* or *Hedysarum*. They laid about 125 eggs on *Vaccinium uliginosum.* Most of the larvae died while being transported to the lab so only eight larvae survived to diapause. They were reared on *Vac. caespitpsum* and diapaused as fourth instar in the lab. Five of the larvae survived overwintering and became adults in June of 2008. The fifth instar larvae have yellow sub-dorsal stripes and white lateral stripes.

The author has collected on the north slope during 11 different years and has not collected this species previously. This species must have just recently invaded this area (global warming?).

The males of C. *pelidne* are similar to the males of C. *gigantea*. The outer margin of the hindwing bulges out more than *C. gigantea*, this gives the hindwing a more square appearance. Also, the underside hindwing is a bit more yellow than *C. gigantea*. The females are easy to distinguish from all other species.

Colias philodice vitabunda
at north slope research site
Fig. 23

Egg: Length 1.36 mm (range 1.30 to 1.44), width 0.49 mm (range 0.47 to 0.53).
Larvae:
First instar: Length 3.2 mm (range 3.1 to 3.4), head width 0.36 mm (range 0.32 to 0.38).
Second instar: Length 4.9 mm (range 4.6 to 5.8), head width 0.55 mm (0.52 to 0.59).
Third instar: Length 8.4 mm (range 7.0 to 10.3), head width 0.80 mm (range 0.73 to 0.87).
Fourth instar: Length 13.3 mm (range 11.8 to 14.5), head width 1.34 mm (range 1.21 to 1.43).
Fifth instar: Only white hairs have been observed. The sub-dorsal stripes are yellow and faint or not expressed. The lateral stripe is white with red on ventral side. Length 24 mm, head width 2.4 mm (range 2.25 to 2.52).
Pupa: There are no sub-dorsal stripes. Length 18.0 mm (range 17.0 to 18.7), width 4.7 mm (range 4.5 to 5.0), height 5.8 mm (range 5.5 to 6.5).

Results

Females have been observed ovipositing on *Hedysarum mackenziei* and *Astragalus arcticus*. The larvae were reared on both species at the research site. The larvae were reared on *Medicago sativa* L. (Fabaceae) and *Astragalus cicer* in the lab.

On June 29 of 2005 one station was established for females to oviposit. Many eggs were obtained but only a few hatched. From July 15 to July 27 five more stations were established and many eggs were obtained and most of these eggs hatched. On August 28 and 29 five second instars were observed in hibernation. Three second instars were still eating and one third instar was still eating. On June 18 of 2006 there were second, third, fourth, and fifth instar larvae observed. On June 22 the first pupa was attained and the first adult emerged on July 9. All total there were 71 adults obtained. All of the larvae pupated and became adults except 8 that became diseased and died as fifth instar or

pupae. On July 13 two fifth instar larvae were left at the research site. When the sleeve was removed on September 8 two dead adults were found. These would have emerged in late July.

Discussion

All of the larvae that were started in 2005 became adults in 2006. Even after a late start in 2005 and a cooler than normal early part of June they completed development in one year. This is obviously the normal habit of this species on the north slope. This results in some individuals flying late in July and early August which was the case in 2005 and 2006.

Colias philodice vitabunda
at Northway

This location is the same as the *C. christina* location. The station was established 10 meters west of the *christina* station.

Egg: Length 1.25 mm (range 1.13 to 1.32), width 0.44 mm (range 0.40 to 0.47).

Larvae:

First instar: Length 3.5 mm (range 3.10 to 3.80), head width 0.35 mm (range 0.32 to 0.38).

Second instar: Length 5.1 mm (range 4.8 to 5.4), head width 0.55 mm (range 0.50 to 0.57).

Third instar: Length 8.2 mm (range 7.2 to 10.8), head width 0.88 mm (range 0.79 to 0.93).

Fourth instar: Length 15.9 mm (range 14.2 to 17.0), head width 1.58 mm (range 1.47 to 1.82).

Fifth instar: Length 33 mm, head width 2.5 mm (range 2.28 to 2.66).

Pupa: Length 20.4 mm (range 18.5 to 21.0), width 5.3 mm (range 5.0 to 5.5), height 6.8 mm (range 6.5 to 7.0).

Results

Females have been observed ovipositing on *Hedysarum mackenziei* and *Astragalus alpinus*. Larvae at the research site were reared on *H. mackenzei* and in the lab were reared on *H. boreale, Astragalus cicer,* and *Thermopsis montana*. On June 17 of 2005 the station was established with two females for ovipositing. As with *christina*, the researcher had to travel on to the north slope. On August 30 two second instar and one third instar lavae in hibernation were observed. A FSS employee removed the sleeve for the winter at the end of September. On May 15 of 2006 the sleeve was reinstalled. At this time the plant had just barely started to grow. No larvae were observed but no effort was made to find them. On July 15 the station was revisited and 3 dead adults were found.

Discussion

It was demonstrated that *C. philodice* completes development in one year. Three individuals do not make a thorough scientific study but they indicate that it is normal for *C. philodice* to complete development in one year. Also, since *C. philodice* on the north slope completes development in one year it is certain that it does here in the interior where the weather is warmer.

Colias christina kluanensis
at Northway
Figs. 27-29, 45, 46

This location is at the airport at Northway which is 7 miles SW of the Alaska Highway and about 50 miles from the Yukon border. This site is the best known colony of *christina* in Alaska. The research station was established 25 meters N of the Flight Service Station (FSS) at the location of 62°57.72'N and 141°56.05'W and an elevation of 518 meters. This is a taiga habitat in the interior which has a longer growing season and is warmer than the north slope.

Egg: Length 1.37 mm (range 1.32 to 1.45), width 0.43 mm (range 0.40 to 0.45).

Larvae:

First instar: Length 3.6 mm (range 3.50 to 3.80), head width 0.35 mm (range 0.32 mm to 0.39).

Second instar: Length 5.4 mm (range 5.2 to 5.8), head width 0.55 mm (range 0.47 to 0.60).

Third instar: Length 8.9 mm (range 8.0 to 9.8), head width 0.90 mm (range 0.80 to 0.96).

Fourth instar: Length 16.1 mm (range 14.8 to 18.0), head width 1.41 mm (range 1.24 to 1.57).

Fifth instar: Some larvae have black hairs and some have white hairs. The sub-dorsal stripes are yellow and on some larvae they are bordered by orange. A few larvae do not express sub-dorsal stripes. The lateral stripes are white with red on ventral side. Length 33 mm, head width 2.6 mm (range 2.30 to 2.75).
Pupa: Length 22.4 mm (range 21.0 to 24.0), width 5.7 mm (range 5.0 to 6.0), height 7.0 mm (range 6.5 to 7.5).

Results

Females were observed ovipositing on *Hedysarum mackenziei* and *Astragalus alpinus*. Larvae were reared on *mackenziei* at the research site and on *H. boreale, A. cicer,* and *Thermopsis montana* in the lab. On June 17 of 2005 the station was established with two females for ovipositing. The researcher had to travel on to the north slope so it was not known until August 30 if there were any larvae. On August 30 three second instar larvae in hibernation were observed. At the end of September the sleeve was removed for the winter by a Federal Aviation Employee (FAA) at the FSS. On May 15 of 2006 the sleeve was replaced. At this time the plant had not begun to grow. One larva was observed which was waiting for food. The station was revisited on 15 July and three dead *christina* adults were found.

Discussion

The larvae that were used for measurements were reared in the lab during 1999, 2000, and 2007. It was demonstrated that *C. christina* completes development in one year. Three individuals do not make a thorough scientific study but they indicate that it is normal for *C. christina* to complete development in one year.

Colias christina* X *canadensis

at Northway
Figs. 14, 15

On June 10 of 1999 a female *C. canadensis* was collected at this location. Eggs were obtained from this female and the larvae were reared to diapause by Ken Hansen. The post diapause larvae were reared by Ken Hansen, Jacque Wolfe, and J. Harry. 16 adults were obtained and all of these adults display characters that demonstrate they are hybrids of *C. christina* and *C. canadensis*. The fifth instar larvae and adults are described.
Fifth instar: Like christina with red along the stripes.
Adults, males: Upper surfaces ground color is orange with the orange completely covering the wing as in *canadensis*. The dark border is wide as in *C. christina*. Undersurfaces appear to be a combination of the two species. Size varies from *C. canadensis* to *C. christina*. The males that are the size of *C. christina* are the largest all orange *Colias* from Alaska, since the orange does not cover the entire surface of *christina*.
Adults, female: Variable like *C.* c*anadensis* and *C. christina* but large like *C. christina*. Undersurfaces appear to be a combination of the two species.

Colias gigantea gigantea

at Northway
Figs. 39-41, 47

Egg: Length 1.44 mm (range 1.32 to 1.65), width 0.49 mm (range 0.46 to 0.53). The SEM pictures of the micropyle demonstrate that different eggs of the same species have a different number of cells around the micropyle.
Larvae:
First instar: Length 3.6 mm (range 3.5 to 3.8), head width 0.37 mm (range 0.35 to 0.38).
Second instar: Length 5.9 mm (range 5.2 to 6.5), head width 0.59 mm (range 0.57 to 0.61).
Third instar: Length 9.3 mm (range 8.6 to 11.8), head width 0.98 mm (range 0.88 to 1.18).
Fourth instar: Length 16.5 mm (range 14.3 to 19.0), head width 1.46 mm (range 1.24 to 1.78).
Fifth instar: Only white hairs on head and body have been observed. The sub-dorsal stripes are yellow. The lateral stripes are white with red on ventral side. Length 33 mm, head width 2.7 mm (range 2.30 to 2.84).
Pupa: Length 23.3 mm (range 22.0 to 25.0), width 6.0 mm (range 5.5 to 6.5), height 7.0 mm (range 6.0 to 8.0).

Results

Females were observed ovipositing on a *Salix* sp. Larvae were reared on *Salix exigua* in the lab.

Discussion

The natural life history was not determined in interior Alaska. The larvae that were used for measurements were reared in 2003 and 2007.

Colias canadensis
at Northway
Fig. 26

Egg: Length 1.30 mm (range 1.20 to 1.40), width 0.51 mm (range 0.48 to 0.60).
Larvae:
First instar: Length 3.3 mm (range 2.9 to 3.5), head width 0.36 mm (range 0.32 to 0.37).
Second instar: Length (N=5) 5.4 mm (range 5.0 to 5.8), head width (N=6) 0.59 mm (range 0.55 to 0.61).
Third instar: Length 9.0 mm (range 8.3 to 9.7), head width 0.92 (range 0.80 to 1.00).
Fourth instar: Length 15.6 mm (range 14.5 to 17.3), head width 1.50 mm (range 1.38 to 1.65).
Fifth instar: Larvae are mostly without sub-dorsal stripes, only 4 of 52 exhibited a hint of sub-dorsal stripes. Length 28 mm, head width 2.6 mm (range 2.25 to 2.85).
Pupa: Length 17.4 mm (range 16.5 to 19.0), width 5.25 mm (range 5.0 to 5.5), height 6.2 mm (range 5.5 to 6.5).

Results

Females have not been observed ovipositing at this location. The females readily oviposit on *Lupinus arcticus* S. Wats (Fabaceae). but will not oviposit on *Astragalus alpinus* in captivity. Larvae were reared on ornamental lupine (russel hybrid) and *Hedysarum boreale* in the lab. All larvae became mature fifth instar the first summer and then diapaused. The larvae pupated the next spring without eating.

Discussion

The natural life history was not studied at this location. The adults start flying in early June which is 20-30 days earlier than the other *Colias*.

Colias canadensis
at Mile 110 Dalton Hwy
Figs. 24, 25

This location is 0.9 km west of the Dalton Highway at Mile 110. The location is 9 km south of the Arctic Circle at 66°29.36'N and 150°43.46'W at the elevation of 690 meters. This location is about 120 meters above treeline on a mixed wet and dry hillside.

Results

Females have been observed ovipositing on *Lupinus arcticus* S. Wats. Larvae were reared on *L. arcticus* at the research site. and in the lab on *Hedysarum boreale* and ornamental lupine (russel hybrid). On June 21 of 2005 five stations were established with females for ovipositing. One female was put in each station. On August 14 four second instar larvae were observed among the five stations. These were at base of the plants so they had already diapaused even though the plants were still in good condition. On August 28 the sleeves were removed for the winter. On May 20 of 2006 the sleeves were installed. At this time the plants had already started to grow with one plant having grown 1.5 centimeters. On July 13 fourteen fifth instar larvae were observed. On September 8 when the sleeves were removed sixteen fifth instar larvae were found. They all had left the plant and had hibernated on the sleeve near the ground. Since they left the plants and tried to crawl away they did not intend to eat in the spring. If they had been left there they would not have been found in the spring so they were taken to the lab. Five of these larvae pupated the next spring without eating. The other larvae died during overwintering.

Discussion

The location at Mile 94 was a much better location than Mile 110. The Mile 94 location is 1.5 miles west of the highway on a flat dry ridge. In 1999, 2001, and 2003 there was an abundant number of adults flying. In 2000 and 2002 there were only a few flying. It was apparent that *C. canadensis* has a two year life cycle at this location and the research verifies this. The majority of adult males taken at this location are *C. canadensis* but a few *C. boothii*

have been collected. Some of the larvae are like *C. canadensis* at Northway, some are like *C. boothii*, and some are intermediate. The two larvae in Figs. 24, 25 are from the same female. It appears that *C. canadensis* and *C. boothi* commonly hybridize at this location or are conspecific. It was hoped to do further research at this location but the area burned in 2004 and there were no adults flying in 2005. In June of 2001 females were sleeved on *Lupinus* plants at Mile 94 Dalton Highway. When the researcher returned 11 days later the eggs were just beginning to hatch. These larvae were reared on *Hedysarum boreale* and ornamental lupine in the lab.

The larvae that died during overwintering had become diseased. They probably became diseased while being transported home.

Concluding Discussion

During the period of July 2005 to June 2006 seven *C. hecla***,** ten *C. nastes*, one *C. palaeno*, and all (71) *C. philodice* completed development. This proves that even during an unfavorable time span some individuals complete development in one year. Then all of the remaining individuals completed development in 2007 (two years time span). Unfortunately, there was considerable loss of larvae the second winter so the numbers were low that completed development in two years.

Nearly all of the *C. nastes* and all of the *C. palaeno* (only one) that were started from eggs in 2006 completed development in 2007. This demonstrates that during a favorable time span most individuals (except *C. boothii*) will complete development in one year.

If a good supply of *C. gigantea* had been obtained it is probable that some individuals would have completed development in one year.

There was a huge loss of larvae from Sept. 8 of 2006 to June 1 of 2007. The cause can only be speculated but all species were affected. It would seem that the most likely cause would be the weather. Whatever the cause was it sure didn't inhibit the Satyrids from having an abundant flight in 2007.

The first winter larvae of all species overwinter in different instars (first, second, third). It is obvious that the larvae do not progress at the same rate in nature. The second winter larvae of *gigantea, hecla, nastes*, and *palaeno* overwintered as fully grown fourth instar. Anytime one of these become fifth instar they complete development without diapausing.

During the second summer the larvae of *boothi* become fully grown fifth instar and then diapaused. *C. boothi* is the only species on the north slope that diapauses as fifth instar. This is the reason that they fly 7-10 days earlier than the other species. However, there are fresh *boothi* individuals that fly with *hecla* and *nastes.*

Colias canadensis and *boothi* are the only Colias in Alaska that diapause as fifth instar larvae.They both diapause as mature fifth instar.

The larvae of some species of *Colias* vary in the expression of patterns and colors. In Utah some larvae of *philodice* and *eurytheme* exhibit sub-dorsal stripes and some do not exhibit the
sub-dorsal stripes. In Alaska some larvae of *christina* exhibit the sub-dorsal stripes and some do not. Also, some *christina* larvae have the orange along the sub-dorsal stripes and some do not. However, all observations indicate that *boothi* is the only species in the *hecla* group that the larvae have the orange along the sub-dorsal stripes.

Quite often when stations were monitored there would be Arachnids on the sleeve or among the rocks at the base of the sleeve. A few times a spider was observed in the process of eating a larvae that was resting on the sleeve. Occasionally a dead larva which had been eaten was found stuck to the sleeve**.** Probably other larvae had been eaten and the carcass fell to the ground. A few larvae were parasitized by Ichneumid wasps and Diptera. The parasites must have stung the larvae while resting on the sleeve.

The larvae that were reared in the lab were under constant light. It is assumed that the constant light would have no affect on the north slope larvae since they have constant light naturally. However one larvae of gigantea in 2007 went straight through to adults which was quite unexpected.

Many of the natural oviposition observations were made in years previous to the start of the study. All of the plant species on which ovipositions have been observed were used in this research. All of the *Colias* species were successfully reared to adults on all the corresponding plant species.

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Table 1. Daily high temperatures (deg. C) at research site.

	Average	2005	departure from average	2006	departure from average	2007	departure from average
May 11-20	2.8						
May 20-31	6.1			9.1	3		
June 1-10	11.5	10.3	-1.2	10.9	-0.6	21.6	10.1
June 11-20	15	16	1	16.7	1.7	18.1	1.1
June 21-30	17.1	18.6	1.5	17.4	0.3	19.1	2
July 1-10	15.9	11.6	-4.3	13	-2.9		
July 11-20	18.4	15.4	-3				
July 21-31	16.9	15.7	-0.8	17.4	0.5		
Aug. 1-10	15.4	20.6	5.2				
Aug. 11-20	12.1	15.6	3.5				
Aug. 21-31	11.9	11.5	-0.4				
Sept. 8				17.8			
5-Jun						29.2	

Fig. 1 - *C. boothii thula* holotype
Mead River, Alaska, USNM

Fig. 2 – *C. boothii boothii* lectotype
Boothia Peninsula, Nunavut, USNM

Fig. 3 – aberrant *C. boothii* male
Dalton Highway, north slope, Alaska

Fig. 4 to 9 – dorsal views of male variation in *C. boothii*, Dalton Highway, north slope, Alaska

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Fig. 10 to 13 – female variation in *C. boothii*, Dalton Highway, north slope, Alaska

Figure 10

Figure 11

Figure 12

Figure 13

Figures 14 & 15 – *C. canadensis* X *C. christina* hybrid male, Northway
Figure 14 – dorsal view

Figure 15 – ventral view

Figure 16 – *Colias boothii* larva

Figure 17 – *Colias boothii* larvae

Figure 18 – *Colias hecla* larva

Figure 19 – *Colias palaeno* larva

Figure 20 – *Colias pelidne* larva

Figure 21 – *Colias nastes* larva

Figure 22 – *Colias gigantea* larva

Figure 23 – *Colias philodice* larva

Figure 24 – *Colias canadensis* larva (Mile 110)

Figure 25 – *Colias canadensis* larva (mile 110)

Figure 26 – *Colias canadensis* (Northway)

Figure 27 – *Colias christina* (Northway)

Figure 28 – *Colias christina* (Northway)

Figure 29 – *Colias christina* (Northway)

Mile 323, 1 July 2002

Figure 30 – *Colias nastes* egg after few days development

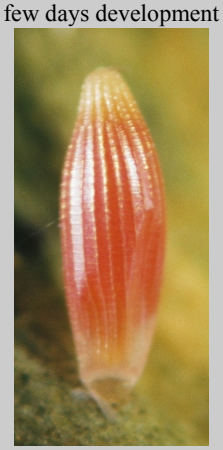


Figure 31 – *Colias palaeno* pupa

Figure 32 – an *in situ* rearing station

Figure 33 – visitors to camp

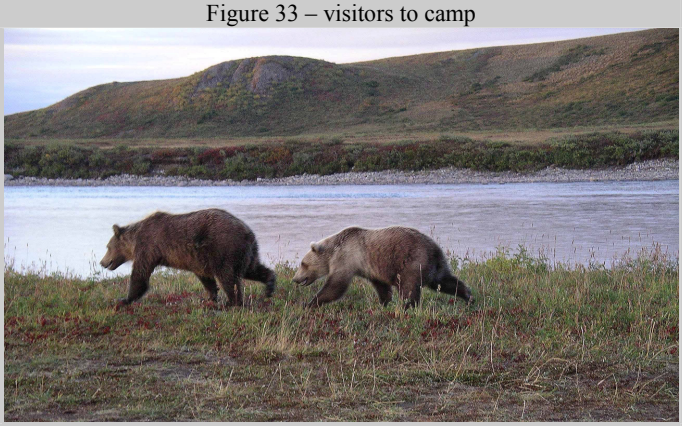


Figure 34 – campsite some days in 2006

Figure 35 – Sagavanirktok River in late May 2006

Figure 36 – campsite looking south to Brooks Range

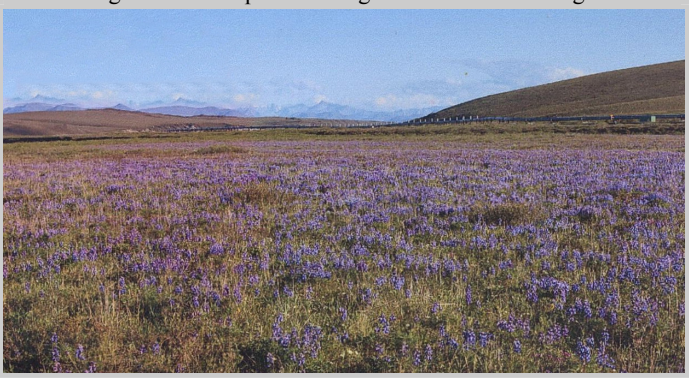


Figure 37 – campsite looking west, note fox

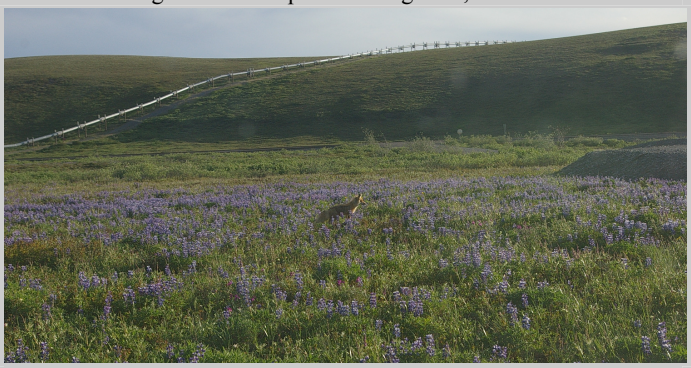
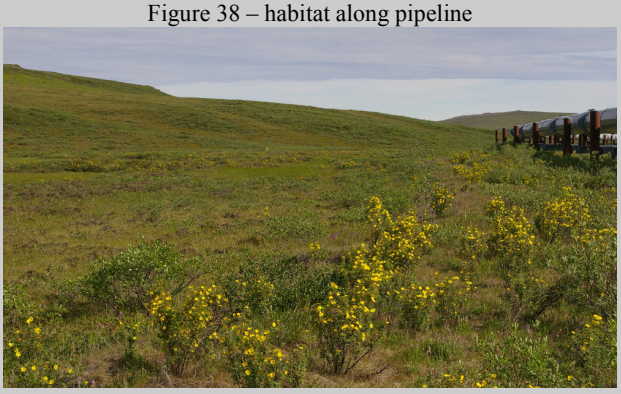


Figure 38 – habitat along pipeline



Figures 39-41: *Colias gigantea* micropyle from Northway

Figure 42: *Colias boothii* micropyle

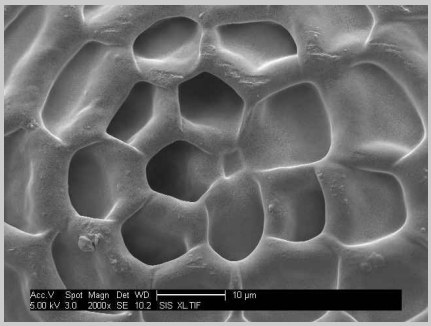


Figure 43: *Colias nastes* micropyle

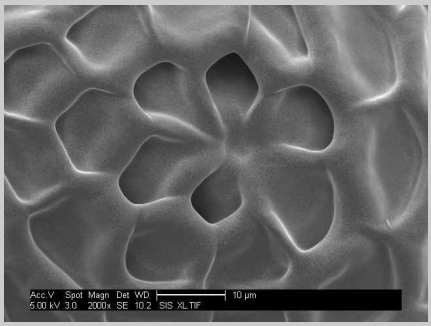


Figure 44: *Colias palaeno* micropyle

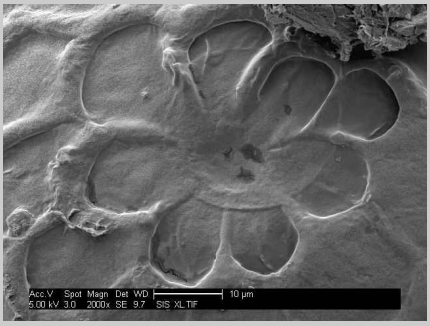


Figure 45*: Colias christina* micropyle

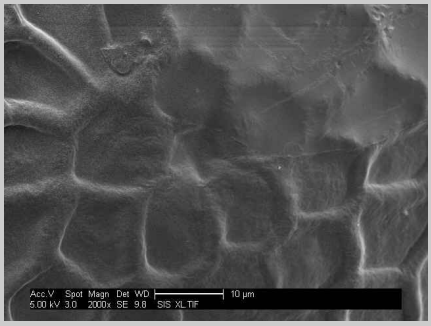


Figure 46: tip of *C. christina* egg, note small holes

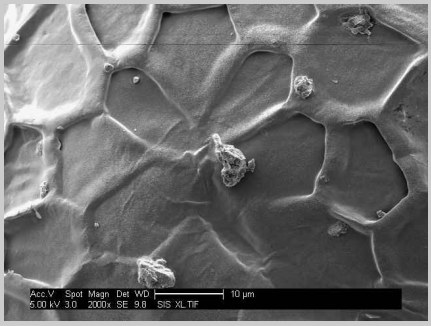
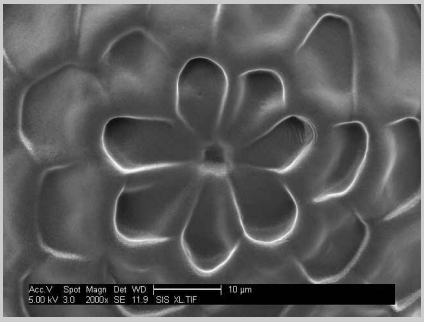
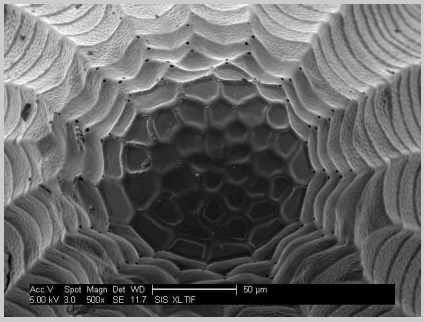


Figure 47: side of *C. gigantea* egg with 2 micrometer holes





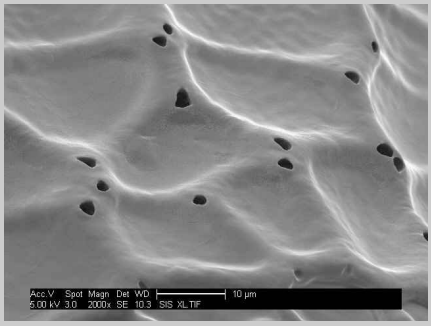


Figure 48 – white male *C. palaeno*
mile 323 Dalton Highway, Alaska

Figure 49 – ¼ gynandromorphy *C. palaeno*
mile 94 Dalton Highway, Alaska

Figure 50 – reared *C. pelidne* male dorsal view
Mile 323 Dalton Highway, Alaska

Figure 51 – reared *C. pelidne* male ventral view
Mile 323 Dalton Highway, Alaska

Figure 52 – wild caught *C. pelidne* female dorsal view
Mile 323 Dalton Highway, Alaska

Figure 53 – wild caught *C. pelidne* female ventral view
Mile 323 Dalton Highway, Alaska

Figure 54 – wild caught *C. pelidne* female dorsal view
Mile 323 Dalton Highway, Alaska

Figure 55 – wild caught *C. pelidne* female ventral view
Mile 323 Dalton Highway, Alaska

APPENDIX 1

Notes on the natural life history of *Papilio machaon* in Alaska

Resume: The results of a brief study of the natural life history of *Papilio machaon aliaska* Scudder on the north slope of Alaska in 2005 are annotated.

The site for this research on the north slope of Alaska is 92 miles (147 km) south of Deadhorse (Prudhoe Bay). This is the same research site as that of the *Colias* research in this publication. The eggs and larvae of *P. machaon* were found on *Petasites hyperboreus* Rydb. (coltsfoot) (Asteraceae) at Sagwon Hills which are 30 miles (48 km) north of the camp site. The eggs and larvae were sleeved on *hyperboreus* near the camp. The materials and methods are also the same as the *Colias* research.

On July 17 of 2005 eight eggs and one first instar larva were put in the first station. On July 18 six first and one second instar larvae were put in the second station. On August 10 there was one fifth and four fourth instar larvae in the first station. Also, on August 10 there were three fifth instar larvae in the second station. It is unknown what happened to the missing larvae. On August 28 the sleeve was removed from the first station for the winter. At this time there were three pupae which were attached to a dwarf birch stem near the ground. On August 28 in the second station there was one pupa, one prepupa, and two fifth instar larvae. The pupa was attached to dwarf birch stem near the ground. The prepupa was attached to the sleeve about 3 centimeters above the ground. The sleeve was reset to another plant with the prepupa and the two larvae.

On May 24 of 2006 the pupae in the first station were missing. It is probable that they were eaten by a vole. At the second station the one pupa not under the sleeve was found. A sleeve was put over this pupa and on June 19 a female adult emerged. There was one pupa attached to the sleeve and 2 dead larvae carcasses. The pupa that was attached to the sleeve died or may have already been dead on May 24. The larvae did not mature and pupate before cold weather stopped them or the food plant became inedible.

The two larvae that did not pupate, died during the winter. Although results from two larvae do not constitute a rigorous scientific study, they indicate that *P. machaon* larvae cannot survive the winter. The larvae and one pupa were under a sleeve so they may not have had proper conditions. A short cold spell during July or August with mild freezing temperatures and snow are not unusual so they must be able to survive these conditions. This demonstrates that *P. machaon* larvae pupate the same season as the eggs are laid.

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