THE URBAN WILDLANDS GROUP

Captive Rearing of Lange's Metalmark Butterfly, 2010–2011

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Final Report to National Fish and Wildlife Foundation

Lange's Metalmark Butterfly Captive Breeding/Rearing Project # 2010-0512-001

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Introduction

The Lange's Metalmark butterfly, *Apodemia mormo langei* (Lepidoptera: Riodinidae) (Figure 1), was placed on the federally endangered species list in 1976. Lange's is restricted to the Antioch Dunes National Wildlife Refuge (narrow distribution), monophagous (extremely restricted habitat specificity), and suffers from a deplorably low abundance. The maximum number of adults observed on a day in 2011 was 32, down from 2,300 in 1999 (unpublished data). These three factors place Lange's Metalmark in Rabinowitz's most rare (and therefore endangered) category of rarity (Rabinowitz 1981; Rey Benayas et al. 1999).

Figure 1. A captive reared Lange's Metalmark butterfly is released to the Antioch Dunes in 2008.

Lange's metalmark was recognized as a subspecies by Comstock (1938). It is univoltine, breeding once per year in synchronization with the flowering of their only host plant, naked-stemmed buckwheat, *Eriogonum nudum* var. *psychicola*, which is a unique variety endemic to the Antioch dunes (Reveal 2007). Adult butterflies emerge from their pupae in late summer (Arnold 1981, 1983). During their roughly one week lifespan in the wild, the butterflies mate and the females oviposit their eggs in small clusters directly onto the buckwheat. The eggs are thick-walled and it is difficult to differentiate between fertile and infertile eggs. The larvae develop within the egg (it is not a true egg diapause) and we have found that most of the hatch occurs in the early spring (Figure 2), while others have reported the fall (Arnold 1981). The first instars will feed on new, tender plant growth. After hatching in the early spring, we have observed the larvae to come in and out of dormancy to feed as temperature allows. Through the spring and summer, the larvae resume feeding and mature before metamorphosing into pupae. About two weeks later, the adult butterflies emerge and begin the cycle anew (Arnold 1981, 1983).

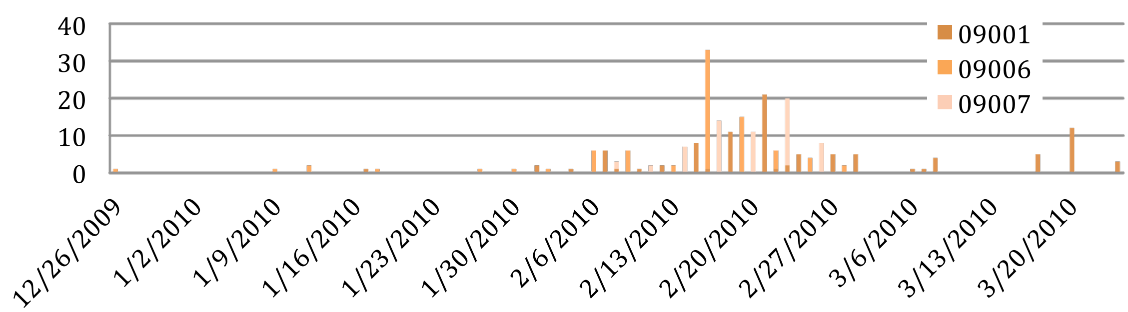

Figure 2. Hatch date for Lange's metalmark butterfly eggs laid in captivity in the summer of 2009.

In 2007, a captive rearing and propagation program was established to guard against extinction, augment the dwindling wild population, and increase knowledge of the autecology of this species. Rearing efforts focused on production the first two years and on data gathering the second two years. This report outlines the 2010 – 2011 season and argues for a return to focusing on production (for the captive stock) because the actions required to collect of data are associated with decreased production.

Rearing for the 2010–2011 season was conducted under the authority of Dr. Jana Johnson as permitted under US FWS SFB-2006-04/1-1-07-F-0114-81420-2008-TA-1515. Additional care was provided by subpermitees who have received extensive training prior to handling the captive stock. The majority of the subpermitees work both with the endangered Lange's Metalmark and the endangered Palos Verdes blue butterflies, which are both maintained at The Butterfly Project.

Captive Rearing Methods

Collection of Wild Females

Ken Osborne, under his FWS permit, collected wild individuals with us on August 28 and again on September 11, 2010 with the oversight of Louis Terrazas (USFWS). Subpermitees were sent out into the field with Ken and shuttled the captured butterflies back to Johnson at a base camp established by the road. The adult butterflies were carried in small vials for this short trip.

Freshly collected individuals are assigned a unique identification code that reflects the two digit year and two digit order of capture in that collection year. For example, foundress 1001 would be the first individual collected in 2010. Some of the individuals collected in the morning will be released in the afternoon, if they show signs of stress from the captivity, prior to the drive back to Moorpark College. Therefore the numbers of the retained foundresses may not be sequential. Individuals returned to the wild are freed at the site of their original capture.

Foundresses 1001, 1003, and 1004 were collected on August 28. Foundresses 1005 and 1006 were collected on September 11, 2010.

Captured butterflies are then handled in a custom-built handling container (similar to an incubator from a NICU in concept) that is attached to an ant free table. They are encouraged to step onto a finger, which allows them to be transferred to a cotton swab saturated with artificial nectar for their initial feeding. This feeding is timed and used as part of the criteria from collection (those unwilling to feed rank lower than those that readily feed). After the initial feeding the females are put in oviposition containers on live buckwheat that has been groomed to remove any arthropods. These individuals are then maintained on an ant-free table in varying degrees of sunlight (according to their behavior) in order to assess their degree of stress from the capture/packaging and to immediately begin collecting eggs. Clear oviposition containers on live plants and Styrofoam ovipostion containers stocked with cut foodplant are used to collect eggs from the captive females. The females are kept in whichever container type they exhibit more oviposition behavior. Typically freshly collected individuals prefer the clear container on live foodplant, while the aging individuals (with less mobility) prefer the styrofoam with foodplant on all sides of the container.

The captured female butterflies are kept in the field all day and driven back to Moorpark College in the evening in order to reduce the deviation from their usual temperature exposure during the course of a day. The butterflies are transported in their oviposition containers in personal vehicles.

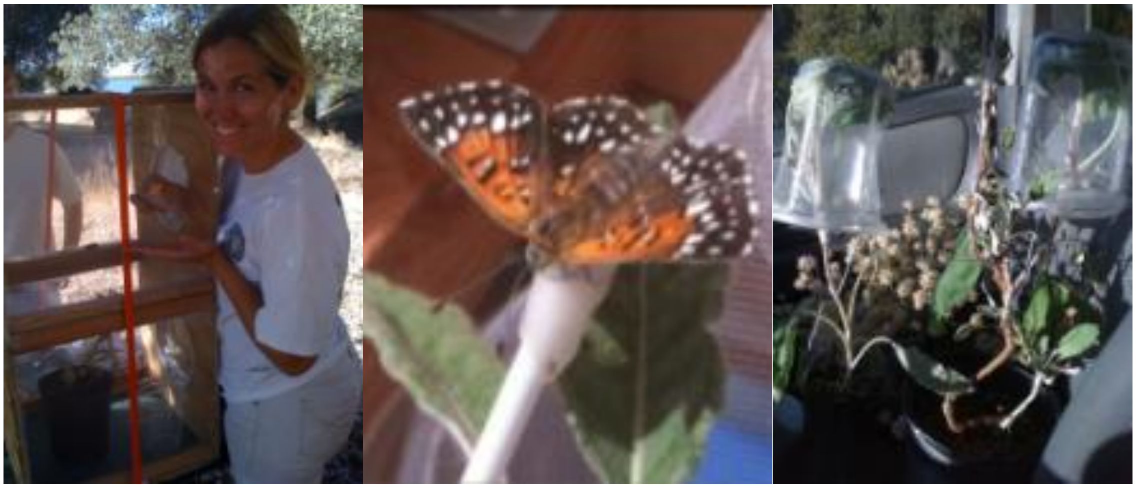

Figure 3. Care for the wild females in captivity in the field just after capture. Left: Dr. Johnson handling butterflies in box attached to ant-free table. Center: Adult butterfly taking nectar from cotton swab saturated with 1:4 honey-water solution. Right: Female metalmarks enclosed in clear/mesh containers over foodplant.

Adult Feeding

Captive butterflies are fed twice daily by hand, in addition to having access to buckwheat flowers and surrogate nectar flowers inside their oviposition container throughout the day.

Butterfly feeding starts at 8:30-8:45 A.M. This allows these ectothermic insects to be warm enough to feed and yet not warm enough to be too active. Replacement plants, which are cleaned and free of insects with a container lid fitted in place, are prepared that morning or the previous afternoon for the number of butterflies that require feeding. These containers have a snug, well-fitting, and well-supported lid attached to the stem of the plant. The individual feeding the butterflies *always* double-checks the fit of the lid.

Because the butterflies are housed outside of the greenhouse, the containers housing the butterflies are brought into the greenhouse to provide an extra level of containment during feeding. The new oviposition container is labeled with the gene line, proper container number (typically 1 new container a day, unless something unusual arises) and the date.

(Ex. 11001 Container 5 9/15-9/16)

Fresh cut flowers (buckwheat and lantana flowers for nectar) are placed among the leaves of the plant in the new container. The container housing the butterfly, the newly made container, two cotton swabs saturated in artificial nectar (1 part buckwheat honey: 3 parts water) are placed in the handling container in the greenhouse.

The butterfly inside its container is located and kept in sight in order to avoid injury while gently opening the oviposition container inside of the handling box. The butterfly is evaluated and notes are taken in her feeding log.

One of the cotton swabs is presented to the female's front feet, within a few feedings the butterflies recognize the cotton swab as a feeding station and step on, lower their proboscis and feed. Feedings are timed and the length of the feeding recorded in the feeding log. While the butterfly is feeding (~ 5–7 min) detailed notes are taken in her feeding log (description of the condition of her wings, thorax, behavior, etc.). If it is cold, the butterfly is allowed to warm up inside the greenhouse before attempting the feeding.

During the feeding, if the butterfly is walking around and probing with its proboscis, this may be a sign that the cotton swab is low on nectar and needs to be changed. A new feeding station is offered in response to this behavior.

After feeding, the butterfly is relocated to the flowers of the new container, which is then gently sealed. Now the handling box may be removed and the seal of the new oviposition container double-checked and the plant tissue from the previous oviposition container may be processed for eggs. After feeding, butterflies are returned to their multibox/unibox where they can receive excellent exposure to sunlight and increased ventilation, while being protected from all non-target species.

The afternoon feeding is the same general process, only it occurs around 4:00 P.M., the greenhouse is used to cool the butterflies prior to feeding, and the females do not switch oviposition containers. Females are kept in a single oviposition container per day unless there is a situation that arises that requires an extra relocation during the day.

Figure 4. Multi-box outside, with each leg in a soapy water solution to keep ants from gaining access to the butterflies within.

Figure 5. Lange's metalmark female in Styrofoam container.

The procedure for feeding with the Styrofoam containers with cut foodplant is slightly different. This procedure may be performed in a smaller handling container. While the butterfly feeds, the Styrofoam container that housed her is removed through the sleeve of the handling container and the vegetation and flowers from inside the container are relocated to an "egg hammock" located on a new container (see Figure 6). This is done with extreme caution; these leaves and flowers may contain eggs. Fresh buckwheat leaves and flowers are harvested and groomed to make sure they are free of non-target species. When the butterfly is done feeding, she is replaced in the Styrofoam-container that has new leaves and flowers and replaced in a containing box outside.

Figure 6. This is an egg-hammock, which is a cup-like container with a mesh bottom that is placed to keep leaves with eggs on them in contact with fresh, live leaves of the foodplant. It keeps all cut egg leaves for a container in one spot and prevents them from rubbing on the container, while keeping them close to the leaves that newly-hatched larvae must locate to begin feeding after they hatch.

Butterfly Containment

Butterflies are under two layer of containment. They are located in their oviposition container and that is stored in a custom-built plywood and screening box that fits one or several containers. These are known as multi- or uni-boxes. These boxes moved during the day to take advantage of sunlight. The butterflies are moved through these various boxes (by hand) to keep them at best exposure to a mixture of direct/dappled light throughout the day, which we have learned maximizes oviposition rates.

Figure 7. Examples of dual containment. Left: Handling box used for feedings inside greenhouse. Right: Containers inside handling boxes outside in dappled sunlight to stimulate oviposition.

Morgue

Deceased individuals are kept in a morgue. This is a growing depository that may be used in the future for genetic testing, *Wolbachia* screening, or samples for museums and other institutions that maintain collections with the proper permits.

Eggs

Eggs are left on the foodplant tissue where they were oviposited and stored in multi/uniboxes at the project. If the plant tissue is live, then the plant is housed with a mesh oviposition container until the end of January to allow for transpiration by the plant. At the end of January, we replace the mesh containers with organza containers, our previous experience with Lange's metalmark has shown that the hatch is in February and the smaller openings in the organza fabric will prevent the first instars from escaping. Putting on the organza too early causes the plants to die from lack of transpiration. Plants are allowed to dry out between watering, overwatering kills the plant. Eggs are checked regularly (about every third day) with a loop for magnification to record the hatch/collapse status.

Figure 8. Left: Inspection of Lange's metalmark eggs using a loop. Right: Lange's metalmark eggs affixed to an *Eriogonum* leaf, as seen through a loop.

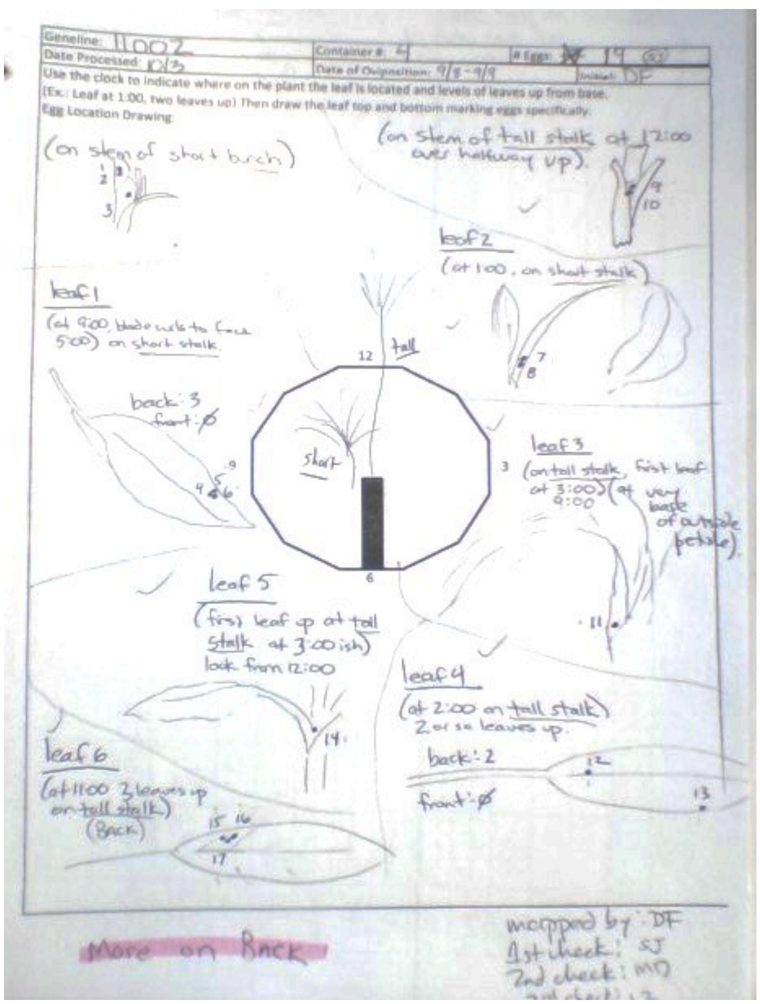

Figure 9. Data sheet documenting location of eggs on foodplant.

Larvae

Larvae were checked regularly (every 2–3 days) by opening the container and using a loop on the younger instars, and by eye once they are large enough. Larvae were only relocated if they needed new, fresh foodplant. Every effort was given to relocate their shelter (silk/frass/foodplant material) with them to save them the energy required to search for and replace it (which occurs when their shelter can not be relocated).

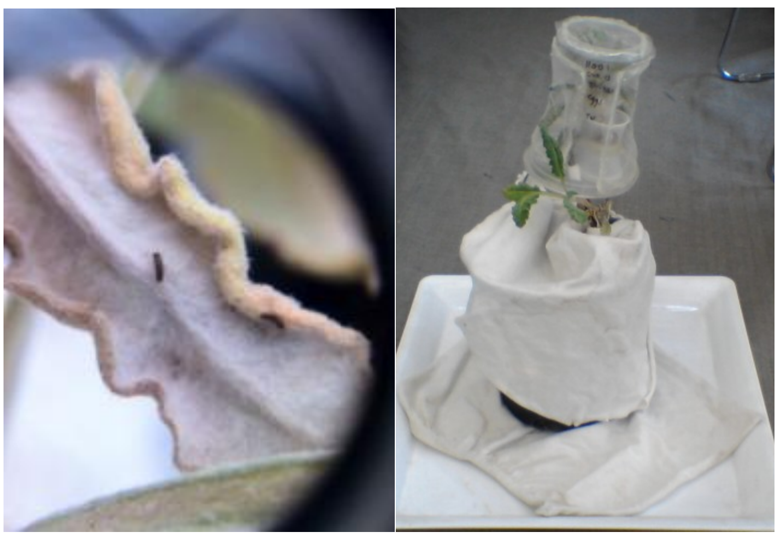

Figure 10. Early instar larvae of Lange's metalmark. Left: Larvae on underside of *Eriogonum nudum* leaf, as seen through a loop. Right: Enclosed in mesh-sided container on foodplant with "soil guard" to help recover any larvae that drop off their foodplant due to disturbance.

Pupae

Pupae are left on the material they are bound to by their own silk. The material and pupae are weighed and then placed in an eclosion cup with a dead/dry buckwheat leaf on top to shelter it from light. The pupa retains muscle filaments that cause it to twitch when exposed to light. This twitching is energetically expensive and there is no way for a pupa to recuperate these losses, so twitching must be minimized.

Figure 11. Left: Lange's metalmark pupae attached to leaf. Right: Eclosion chamber with dividers to track individual pupae.

Eclosion had just begun on August 14, 2010, the close of this reporting period.

Results

Average longevity of the wild-caught females was 11.6 days, although their age at capture was unknown. The average egg production was 57.2 eggs/female. Excluding female 1001, which was an outlier (produced one, infertile, malformed egg and died young), longevity rises to 12.3 days and average fecundity increases to 71.3 eggs/female. Also excluding 1001, the average numbers of eggs laid per day by female were 5.6, 6.2, 9.2 and 12.

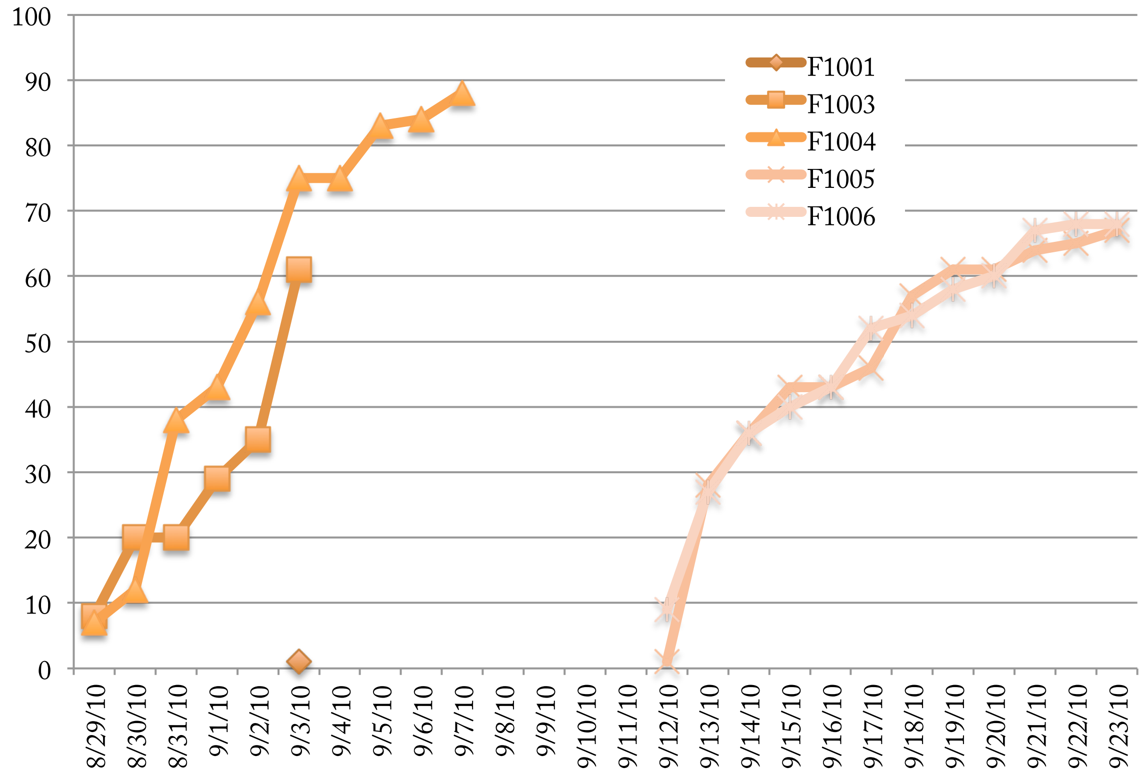

Figure 12. Egg accumulation curves for 5 female Lange's metalmarks collected in 2010.

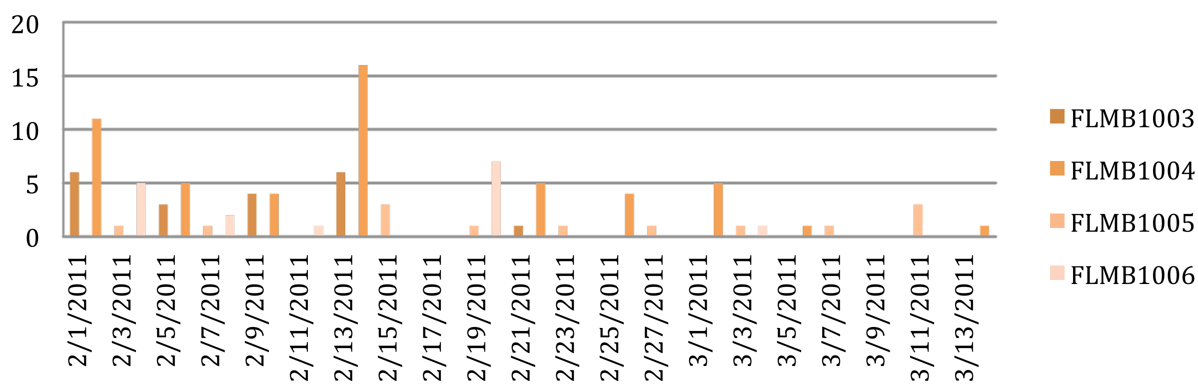

Figure 13. Hatch dates for eggs from Lange's metalmark butterflies captured in summer 2010.

None of the eggs hatched in the late fall, but rather hatched starting on February 1, 2011 and extending until March 13, 2011 (Figure 13). We recorded maximum temperatures on all days when eggs hatched and pooled these data with the results from 2010. Eggs hatched on days with maximum temperatures ranging 62–88 °F, with a mean of 76.2±25.8 S.D. °F (n=348) (Figure 14).

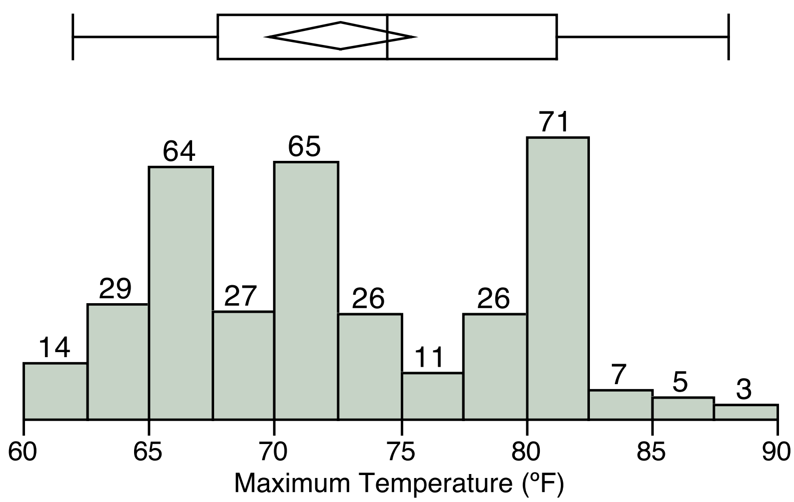

Figure 14. Distribution of maximum temperature (°F) on hatch day for eggs in 2010 and 2011.

We recorded several different outcomes for the eggs:

- Failed to hatch – the egg was intact and never hatched;
- Collapsed – the egg collapsed, a sign of infertility;
- Missing/Unknown – we were unable to account for the egg, which does occur, given their small size;
- Partial hatch – the larva started to emerge from the egg but died in the egg before completing the hatch; and
- Hatched.

Only 35% of the eggs (101/285) hatched and of those only 19% (19/101) reached pupation (Table 1). This was a low compared with previous years when containers were opened less frequently but fewer data were collected (Table 2). Losses of larvae were high in the early instars (Table 1).

Table 1. Survival of Lange's metalmark eggs and larvae by geneline, 2010–2011.

	Geneline				
	FLMB1001	**FLMB1003**	**FLMB1004**	**FLMB1005**	**FLMB1006**
Total Eggs	*1*	*61*	*88*	*67*	*68*
Failed to Hatch	1	32	26	38	37
Collapsed	0	2	2	14	7
Missing/Unknown	0	2	5	2	8
Partial Hatch	0	5	7	0	0
Hatched	*0*	*20*	*48*	*13*	*16*
Larvae Died Month 1	0	8	23	7	12
Larvae Died Month 2	0	11	5	1	2
Larvae Died Month 3	0	0	0	0	0
Larvae Died Month 4	0	0	3	2	0
Larvae Died Month 5	0	0	1	2	0
Larvae Died Month 6	0	0	4	0	1
Larvae Died Month 7	0	0	0	0	0
Pupae	**0**	**1**	**16**	**1**	**1**

Table 2. Oviposition, hatch, and pupation of Lange's metalmark for 2007–2008 and 2010–2011 seasons with average number of times that each rearing container was opened during the process.

Year	Openings per container	Number of eggs	Number hatched (% of eggs)	Number of pupae (% of hatched eggs)
2007 – 2008	9.5–11.5	286	218 (76.2%)	70 (32.1%)
2010 – 2011	36	285	101 (35.4%)	19 (18.8%)

In addition to the eggs obtained from wild-caught females, we had thousands of eggs from females that were from the previous year's cohort. These females had been set up in Styrofoam containers with males and every effort made to induce mating, but by March it was apparent that none of the eggs would hatch and were almost certainly infertile.

Discussion

Collection

Collections have run very smoothly. We typically collect and keep 5 foundresses or 10% of peak flight. We have found that about 1 in 5 females collected will be infertile, suggesting that there may be some Allee effects occurring in the population (Calabrese & Fagan 2004).

Oviposition and Adult Maintenance

We have been successful in stimulating oviposition in captivity and extending the longevity of the adult butterflies (est. 3–5 days in the field). Our captive females lived 1, 6, 10, 15, and 15 days (mean = 9.4 days). The procedures developed over the past 4 years are working well and continue to be adjusted as necessary.

Eggs

The mapping and counting of eggs is an excellent system that has built a database that will be revisited for future research. The counts and maps are quadruple checked during the September–December months. The maps suggest that the current literature that state oviposition is at the base of the petiole (Black & Vaughan 2005) is inaccurate. Females do oviposit there, but they also oviposit on the top of the leaf, bottom of the leaf, along the edge of the blade, next to the midvein of the blade, all along the petiole and on the stem itself. Females do prefer blades with more topographic relief to them, giving plenty of indentations to house their eggs.

Eggs have been a challenge. Due to issues with partial hatches (where the first instar starts to hatch and then fails to complete the hatch, dying inside of the egg) when eggs are stored apart from living foodplant, we store our eggs on/with living foodplant. This does produce conditions where some eggs to be covered by mold/fungus. It should be noted that mold/fungus does not necessarily mean the death of the egg; we have seen these hatch successfully. The treatment of mold/fungus with bleach water is ill-advised because using a concentration that is high enough to kill the mold/fungus may also kill the egg and using a concentration that is dilute enough to preserve the egg usually promotes fungal/mold growth due to the addition of water and the bleach being too dilute to kill.

A very few eggs will hatch during the September–January time period and the larvae that hatch early have a high mortality rate. With our protocols and in our location, the main hatch is in February, when the weather begins to warm up. Our eggs for 2010-2011 were stored at ambient temperature in the multi/uniboxes outdoors.

We had better production in the first two seasons of rearing compared to the last two seasons. Two major changes have occurred. In the most recent two years, the eggs were not kept in the greenhouse with a heater for the December–February months to guard against dipping under 40 °F and we increased the handling of the plants with eggs and larvae on them to gather more detailed data. For the 2011–2012 season, the eggs are being housed in the greenhouse with a heater to prevent their temperature profile from dipping below 40 °F. Although the Antioch dunes do experience lows in the thirties, those temperatures are relatively stressful on eggs and may be an early selective agent that we have decided to eliminate.

A set of eggs from a fertile Lange's metalmark female that did not hatch in the February following their oviposition were maintained for two and one half years to check for multi-year egg diapause. They eventually collapsed.

A few eggs are lost during their care. Their attachment to the leaf's trichomes can be tenuous (especially if the female was geriatric at the time of oviposition) and may fall free. The intensive data that we have taken over the past two seasons has increased our understanding of the species, but seems to have reduced the survival rate of eggs and larvae.

Larvae

Larvae are similar to eggs. They survive better with fewer disturbances, but this precludes recording data. Losses of larvae are reported to be high (Arnold 1981). Losses are highest during the first two instars (the first three months) (Table 1). Larvae do not like to be disturbed at all and if accidentally disturbed tend to let go of the foodplant and fall to the substrate, wrapping themselves into a small ball (reminiscent of pillbugs). Because of this behavior, we use soil covers to insure that the instars do not fall into the soil where they cannot be recovered. It is very difficult to recover the smaller instars that fall to the soil cover due to vibration/disturbance. The first instars are the size of half an eyelash. To return them to the plant requires pulling a piece of tissue apart and using the paper fibers to ensnare the first/second instar and then wedging the tissue between the stem and the petiole of a leaf and leaving the instar to crawl free and back onto the plant. Although the data on the hatch from the past two years has been invaluable in expanding our knowledge, it has reduced production and in the 2011–2012 rearing season we will only open containers with eggs or larvae only when absolutely necessary.

Pupae

Care for pupae has improved drastically over the past 4 seasons. They are extremely delicate and in laboratory conditions prefer to pupate in communal shelters. They need to be protected from light to avoid expending energy during pupation. The data sheet and the weighing system for the pupae has worked very well this year and will provide further insight into the details of this step in the rearing process.

Breeding

It is incredibly difficult to stimulate metalmarks to mate in captivity. Arnold (1981) did not attempt breeding, and we are the only facility that has successfully bred Lange's metalmark in captivity (fall 2007). We were unable to duplicate that accomplishment in fall of 2009 or 2010. We continue to try to get the correct cues to create a reliable breeding setup.

Educational Outreach

Our rearing facility is at an educational institution that is open to the public, although our facility is secure. We have developed tri-fold pamphlets for youth that we use both with the young zoo patrons and with outreach to schools (both locally and via email inquiries across the nation). These are available at the fence outside the facility (Figure 15). A case study appropriate for late high school and lower division undergraduate classes was also developed and distributed by Moorpark College students. See appendix for examples of these materials.

Figure 15. Information sheets available to the public on Palos Verdes blue and Lange's metalmark captive rearing projects at America's Teaching Zoo at Moorpark College.

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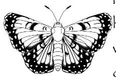
Lange's Metalmark butterfly is a tiny insect we are trying to save here at the Butterfly Project at America's Teaching Zoo. This butterfly is smaller than most expect. Its wingspan is only a little larger than a quarter! Its natural home is near San Francisco, where there once were huge sand dunes. Currently there is a small protected area for them called the Antioch Dunes National Wildlife Refuge.



Here at the Butterfly Project, we attempt to care for and increase their numbers, while many others support us, do research, care for the remainder of the wild habitat, as well as care for the naked stem buckwheat. The fate of Lange's Metalmark is dependent this rare plant. The larva of this butterfly feed on the leaves of the naked stem buckwheat, and, as an adult, the imago drinks the nectar and lays its eggs on the leaves and stems.

It is a lot of dedication and hard work, but it is well worth it to the people involved in saving this amazing and beautiful little creature!

Groups working to save this butterfly:

The Urban Wildlands Group, Inc.
Moorpark College
Antioch Dunes National Wildlife Refuge
U.S. Fish and Wildlife Services
Central Valley Project Conservation Program & Project Improvement Act
UC Davis
Washington State University
Pacific Gas & Electric
U.S. Geological Survey
California Conservation Corps
Contra Costa Fire Safe Council
National Fish & Wildlife Foundation
Deer Valley High School

Butterfly Word Search

L	A	S	G	G	E	L	I	Q	I	B	O	I	P	E
A	Q	O	S	Y	I	N	H	X	H	H	G	C	U	F
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A	T	W	G	H	M	E	U	C	F	Y	K	N	Z	M
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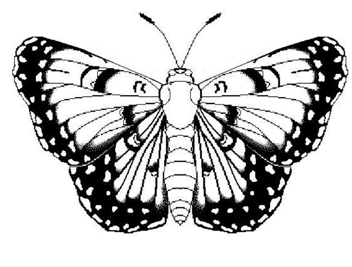
A	R	U	U	C	I	O	G	Y	V	F	A	J	J	S
R	D	B	A	H	R	S	R	A	L	U	P	M	O	W
K	A	X	J	U	V	E	N	T	I	L	A	T	E	D

BUCKWHEAT
BUTTERFLY
COLLECT
DUNES
ECLOSE
EGGS
HATCH
HONEY
IMAGO
INSECT
INSTAR
LANGE'S METALMARK
LARVA
PUPA
PUPATE
VENTILATED

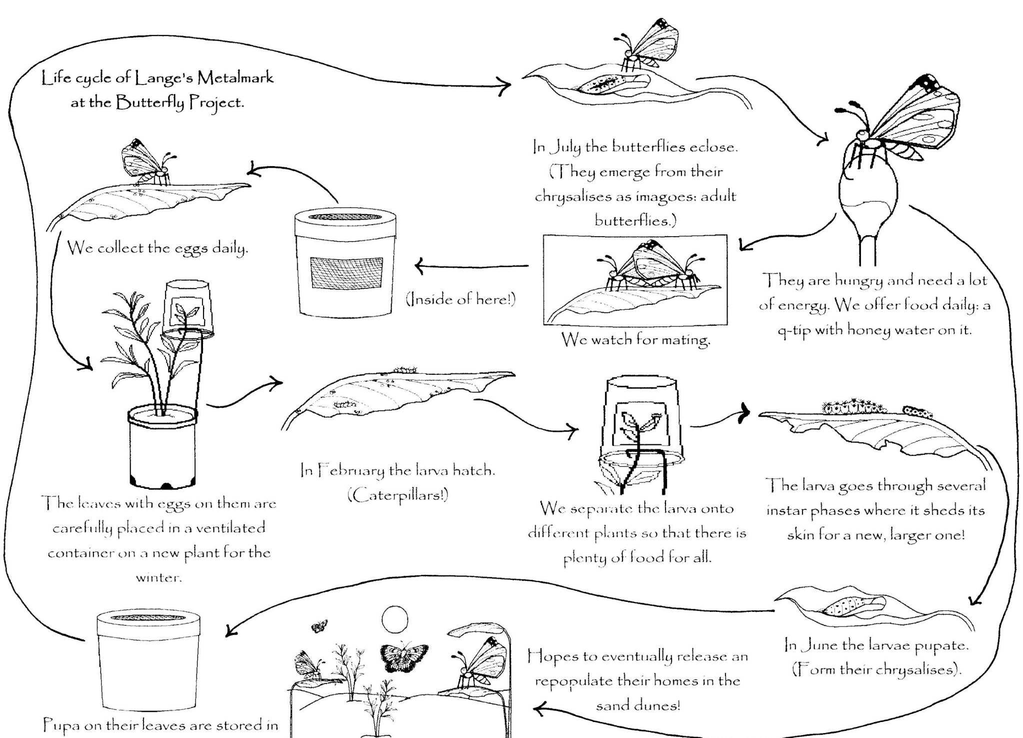
Bonus: *Can you find each of these words elsewhere in this pamphlet?*

For Ages 10 and Up...

Lange's Metalmark Butterfly



1. Color the eyes green.
2. Leave all of the dots white.
3. Color the body brown.
4. Color the rest orange!



Draw a line to connect the picture to the word...

BUTTERFLY

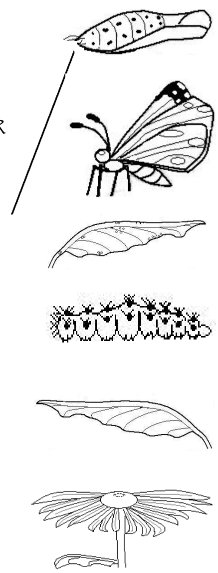
CATERPILLAR

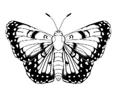
CHRYSALIS

EGGS

FLOWER

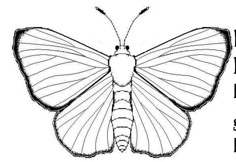
LEAF





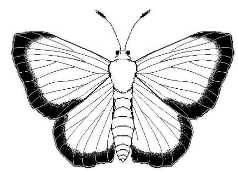
For Ages 5 to 9 Years...

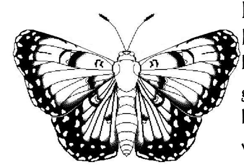
Butterflies



Palos Verdes Blue male butterfly has a gray body with blue wings.

Palos Verdes Blue female butterfly has a gray body with blue wings.



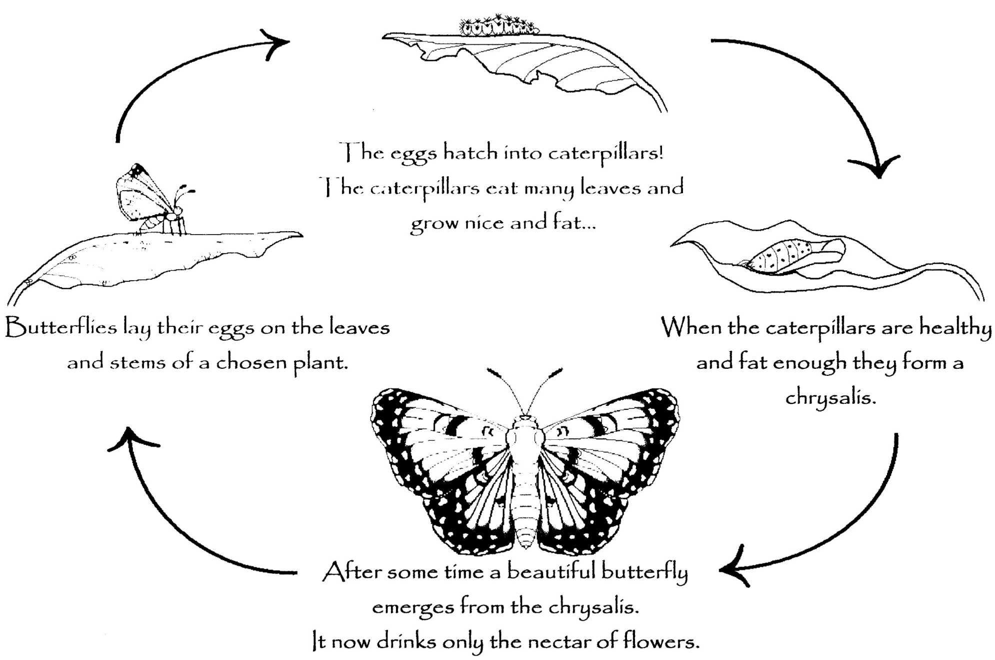


Lange's Metalmark butterfly has a gray body and has orange wings with white dots.

Groups working to save these butterflies:

- US Navy
- US Defense Logistics Agency
- US Department of Defense
- U. S. Fish and Wildlife Services
- The Urban Wildlands Group, Inc.
- Moorpark College
- America's Teaching Zoo
- Palos Verdes Peninsula Land Conservancy
- LA Parks & Recreation
- Antioch Dunes National Wildlife Refuge
- Central Valley Project Conservation Program & Project Improvement Act
- UC Davis
- Washington State University
- Pacific Gas & Electric
- U. S. Geological Survey
- California Conservation Corps
- Contra Costa Fire Safe Council
- National Fish & Wildlife Foundation
- Deer Valley High School

The Butterfly Life Cycle...



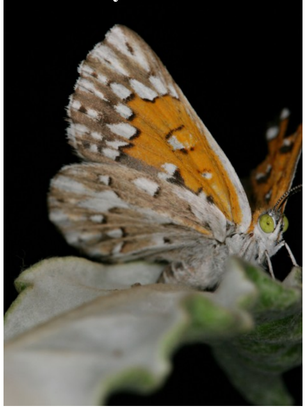


Photo by: Fred Vacchs

A Case Study in Conservation Biology: Lange's Metalmark Butterfly

Inside this Case Study:

Try to apply these lecture concepts as you read this case study:

- Allopatric speciation
- Ecosystem
- Biodiversity
- Endemic/Exotic
- Definition of a Species
- Rarity
- Predation
- Complete metamorphosis
- Cladistics/Phylogeny
- Conservation Biology

The Ecosystem: The Antioch Dunes of Northern California

The Antioch Dunes are located in the San Franscico-Bay Delta along the banks of the San Joaquin River. The once 100-foot high dunes stretched for 9 kilometers. This relic dune system was isolated when the Mohave Desert receded (pre-historic). In this isolation, a unique community evolved resulting in two endangered plants (the Antioch Dunes evening primrose and the Contra Costa wallflower) along with one endangered insect (Lange's Metalmark butterfly).

After the San Francisco earthquake of 1906, sand was needed for rebuilding the city. When you walk around San Francisco and see yellow brick buildings, remember the dunes.

The sand mining removed the dunes (basically down to deadpan soil) and development in the area reduced the open space to just 67 acres.

An additional challenge faced by the endemic species is the encroachment by exotic grasses and vegetation. Bromus grasses have been especially competitive.

How can geographic isolation lead to speciation and a suite of unique endemic species?


Photo by: Adam Clause

Legal aspects: Endangered Species Act saves the last 67 acres of Antioch Dunes

In 1980, The Antioch Dunes national Wildlife Refuge was established. This was the first refuge founded to protect endangered plants and an insect.

The Endangered Species of Act of 1973 provides for the protection of species that are listed as threatened or endangered. The concept is to protect biodiversity (richness, genetic, and ecosystem biodiversity).

ESA law carries monetary penalties and jail time for adverse impacts on listed species.

Antioch Species	Year Listed
Lange's Metalmark	1976
Antioch Evening Primrose	1978
Contra Costa Wallflower	1978

Why was the establishment of the refuge justifiable under ESA law? (tie it to biodiversity)

Definition of a Species

Captive Lange's Metalmark ovipositing eggs (two to the right of her abdomen). Photo by: John Hannah

Lange's Metalmark butterfly was described and recognized as a subspecies in the *Apodemia mormo* species complex in the 1938 by Comstock and named for an entomology student (Lange).

Lange's Metalmark was described as having a wingspan from 1 — 1 1/2", dorsal wings that are largely black with white spots. The red-orange coloration extends through the inner forward half of the forewing, the hindwing bases, and a small central patch. On the ventral surface the wings are predominantly gray, white, black and orange.

Lange's occurs only at Antioch Dunes and its larvae consume only *Eriogonum nudum auriculatum* (Naked-stem buckwheat).

In an effort to have a refugium (captive population that is an insurance policy for the wild population that is imminent danger of extinction due to low population size), 9 adult females were pulled into captivity and their eggs collected and reared. These offspring were used to augment the population, prior to release a "wing pinch" procedure resulted in collection of genetic material for future DNA work (when funding allows).

How many definitions of species do you see in this discussion?

Rabinowitz' Seven Forms of Rarity

Rarity can be a completely natural state OR the symptom of a species about to go extinct. How do you separate the two?

Rarity can be a completely natural state, unrelated to threat of extinction. Rarity is also the state that occurs just prior to extinction. Separating these two types of rarity is a dilemma.

Specificity of habitat use impacts rarity. The more specific (specialist) the species' requirements from the environment, the less common it will be.

Distribution of a species will also impact its rarity. If a species occurs across a wide area it will be more common than if it is restricted in its distribution.

Finally, the population size will impact the rarity of a species. If there are only a few individuals left, then it will be rare.

It is the interaction between these components that create 7 forms of rarity and 1 category of "common." The rarest species is a specialist, with a limited distribution, and small population size.

How does Lange's fit these measurements of rarity?

Predation

Wasp parasitizing a gypsy moth larva (no parasitism in the captive breeding program and therefore no LMB photo). (photo from online Tree of Life project)

Predation can take many forms. Predation can mean true predators that kill and consume many of their prey over the course of their lifetime. Predators that benefit from preying upon Lange's Metalmark include spiders, ants, lizards, and birds.

Herbivores are also predators, they are predators who consume a portion of many prey without killing the prey. Lange's larvae inflict feeding damage on their host plant *Eriogonum nudum auriculatum*.

Parasitic wasps (Hymenoptera) are a form of predation as well. They are parasitoids. The wasps oviposit their eggs inside of the Lange's eggs and larvae which are consumed from the inside out by the developing wasps.

What type of predation is not discussed here?

Life History of a Butterfly

All too frequently you will hear "my butterfly garden is being destroyed by caterpillars." The failure to understand that this is actually the ultimate complement from the adult butterflies who left their eggs which hatched into their children (caterpillars/ larvae).

Butterflies undergo complete metamorphosis resulting in four life stages: egg, larva, pupa, imago (adult). Adults reproduce sexually with the males breeding as many times as they are able and females breeding just once. Females will receive a spermatophore during mating and then be gravid (fertile) for the rest of her life. She will use sperm from the spermatophore to fertilize her eggs prior to placing her eggs on the buckwheat with her ovipositor (oviposition). The larva develops in the egg and will eat the micropyle area to exit the egg. The larva that emerges from the egg is known as a first instar. It will eat and grow until it has to shed its cuticle and head casing. After the molt, it is known as a second instar. This continues through six instars and then pupation. There is a complete reorganization in the pupal stage where the larva will break down to a cellular biological goo and then form the adult butterfly. Eclosion is the emergence of the butterfly from the pupal casing, which involves both environmental and hormonal cues.

Cladistics and their defining characteristics for *Apodemia mormo langei*

Butterflies are a part of these clades. If a clade is "unranked" then it is referred to by the generic "Clade" (each clade splits out from the previously listed clade with more recently developed evolutionary traits):

Domain Eukaryota grouped based on shared cellular organization, biochemistry and molecular biology. (e.g. membrane bound organelles)

Kingdom Animalia multicellular organisms with an extracellular matrix composed of collagen, proteoglycans, adhesive glycoproteins, and integrin.

Subkingdom Eumetazoa are animals that have tissues organized into germ layers and that form a gastrula during development.

Clade Bilateria having bilateral symmetry.

Clade Protostomia based on a protostome developmental pattern.

Superphylum Ecdysozoa has an exoskeleton (cuticle) that must be shed (ecdysis) in response to hormones (ecdysteroids).

Phylum Arthropoda have a cuticle composed of chitin and protein, segmented bodies, and jointed appendages.

Clade Uniramia have uniramous appendages, meaning that their legs only branch once.

Subphylum Hexapoda have six walking appendages and a thorax formed by the fusion of three body segments.

Class Insecta with a lack of musculature beyond the first segment of the antenna, presence of Johnston's sensory organ in the second segment of the antenna, subsegmentation of the tarsi, females with an ovipositor formed from portions of the 8th and 9th segments of the abdomen.

Subclass Pterygota the winged insects.

Infraclass Neoptera which are insects that have the ability to fold their wings back over their abdomen. This characteristic has been secondarily lost in Lepidoptera.

Superorder Endopterygota which are the insects with complete metamorphosis (covered in life history above).

Order Lepidoptera means "scale wing" and their wings are covered by microscopic scales. They have chewing mouthparts as larvae, that may or may not be modified as adults.

Family Riodinidae named for the metallic marks on their wings, characterized by males with modified forelegs, unique venation on the hindwing, and "hairy" larvae,

Genus *Apodemia* is a North American genus.

Species *Apodemia mormo* is identified morphologically, along with flight pattern and host plant.

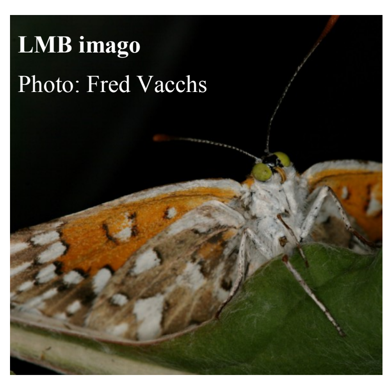
Subspecies *A. m. langei* (please see definition of a species on previous page)

LMB eggs, top one hatched. Photo by: Fred Vacchs

First instar LMB larva fresh from hatching out of the egg. Photo by: Fred Vacchs

Fourth instar LMB larva on hostplant leaf. Photo by: Adam Clause

LMB chrysalis on foodplant leaf with final shed at tip of the abdomen. Photo by: Adam Clause



LMB imago
Photo: Fred Vacchs

MOORPARK COLLEGE

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Logo by: Damien Renner

The Butterfly Project

Mission Statement

Is a cooperative effort between Moorpark College and The Urban Wildlands Group that serves as a model for Cooperative Conservation efforts. We work to recover butterflies and their habitat. We provide excellent care for our guests, increasing their numbers, and releasing them to the wild (in their native habitat) as quickly as possible. We perform investigations improving our understanding and, therefore, the quality of their care and speed of their recovery. We have Moorpark students applying their biology coursework with internships. We inform the public on the plight of the disappearing butterflies and the amazing teamwork involved in the recovery effort.

Conservation Biology through Cooperation

Suggested resources:

- http://www.fws.gov/sfbayrefuges/antioch/
- http://urbanwildlands.org/
- http://www.npwrc.usgs.gov/resource/wildlife/recoprog/states/species/apodmorm.htm
- http://www.ucmp.berkeley.edu/exhibits/historyoflife.php
- http://www.tolweb.org/tree/

Conservation biology involves multiple partners coming together to actively apply the biologically based concepts they have learned to solve a crisis. Unfortunately, rarely is there the opportunity to come together to be proactive.

Currently US FWS, Central Valley Project Conservation Program, The Butterfly Project (a cooperative effort between Moorpark College and The Urban Wildlands Group), UCD, and USGS are working in concert to solve the crisis of LMB and the Antioch Dunes.

Central Valley Project Conservation Program has provided funding for the recovery efforts.

The Butterfly Project is the site for captive propagation. This allows for a refugium population during habitat manipulation and excess individuals can be released to the wild to augment the wild population. Research is also performed to increase our knowledge of the species and aid in restoration efforts.

UCD is performing extensive field work. This includes a grazing experiment (using HILF...high intensity low frequency grazing to reduce exotic grass cover) and microclimate data collection and analysis.

USGS is mapping the foodplant, open soil, and attempting to install a weather station. They are very interested in using GIS to analyze the habitat.

US FWS actively manages the dunes and oversees all the partners efforts. Communication is key to the success of this team as we coordinate our efforts and strive to have help each other in our various roles.

Hopefully this will help the dunes be what they once were...though in a fragmented habitat, constant, vigilant, active management will always be required in a disturbance system surrounded by developments that tend to stabilize the dunes and destabilize this unique ecosystem.