Study of the Anisoptera of the University of Notre Dame Environmental Research Center at Gogebic County, Michigan Summer of 1992

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Abstract

A survey of Anisoptera on the UNDERC property was conducted throughout the sumer of 1992 and twenty - eight species were found in a wide diversity of habitats. New species found in adult form on the property include Sympetrum atripes, Neurocordulia molesta, and Leucorrhinia patricia. Two mark - recapture studies were conducted on the property. The first study was conducted at the road between Plum and Inkpot Lakes and a population estimate of the Gomphus spicatus was made at 592, and the population of the Ladona julia was estimated at 304. At the second site the Libellula quadrimacalata was estimated at 1966. The larvae of the Libellula quadrimaculata also demonstrated preferences for mosquito larva, which seem to come in the order: Aedes trisereatus, Wyeomyia smithii and Culiseta morsitei. It was observed that by depriving larval dragonflies of prey they did indeed consume at a much higher rate than did those dragonflies that had been fed previously. In addition it was observed that cold temperatures were indeed responsible for lowering the metabolism in larval dragonflies.

Introduction

The study of the Anisoptera at the University of Notre Dame Environmental Research Center (UNDERC) in Gogebic County, Michigan was conducted in accordance with the proposal of April, 1992 between the period of May 19, 1992 and July 23, 1992. This property encompasses 7345 acres and includes thirty lakes and bogs. These include a variety of aquatic habitats such as dystrophic bogs, permanent ponds, marsh and lake habitats. This makes UNDERC an excellent location for studies of Anisoptera, as it is made up of a variety of dragonfly breeding habitats. A wide variety of species thrive throughout the region. The fact that the area is virtually untouched by any civilization besides researchers allows these dragonflies to remain in a natural habitat uninhibited by sources of external pollution or disturbances.

The following proposed objectives of the research project were indeed accomplished.

1. The collection of 28 species (both sexes in most cases) of adult dragonflies from a variety of sites throughout the UNDERC property.
2. 3 species will be added to the presently existing species list of Anisoptera collected at UNDERC.
3. Pictures were taken of killed and pinned dragonfly specimens in order to supplement the existing photographic manual of dragonflies at UNDERC.
4. Two Mark - Recapture studies were performed. One was done with the assistance of the class at the Plum \ Inkpot site (measuring close to 100 yards in length), and focused on the population of dragonflies of the Ladona julia as well as the Gomphus spicatus. The second study was conducted by a single investigator (Christine M. Ciervo) at thebog across from the Bog Pot site on the population of the Libellula quadri-maculata
5. The study of feeding behavior of dragonfly nymphs was conducted. Nymphs were studied in the laboratory environment in order to observe magnitudes of consumption of mosquito larvae on a normal basis with comparison to consumption rates of other nymphs following a deprivation period.
4. Territorial behavior was also studied through field observation and experimentation (the Mark- Recapture studies)
5. Observance of the emergence process in the field was conducted. Unfortunately observance of such emergence within the lab was unsuccessful as those nymphs which were maintained within the lab throughout a four week period either died or failed to emerge.

6. A bionomic knowledge of certain species was accumulated.

Those studies which were developed and accomplished following the original proposal of the project include:

1. Certain species of dragonfly larvae were studied for their preferences for certain mosquito larvae.
2. The effects of temperaature on the metabolism of dragonfly nymphs were studied.

Method

A day of dragonfly collecting would require a number of instruments including an insect net (better known as an aerial net), one or more killing jars (containing a chemical solid of potassium cyanide), labelled storage jars (containing paper towels for the collection of moisture), forceps, and a hand lens when possible.

A day of dragonfly collecting usually consisted of a visit to each of three different sites on the UNDERC property. Each visit was in most cases one to two hours in length. This field work was followed by pinning proceedure in the lab. In most cases pictures of the same dragonflies were taken in the late evening or early morning of the next day. This was to insure that the colors of the dragonflies were not lost prior to the photographing process. Early on in the project it was necessary that the photographs be taken prior to identification of the insects. However, as the investigator became more familiar with the species on the UNDERC property, identification of the dragonflies became much easier and the investigator was able to identify the insects prior to photography.

Over the course of the ten weeks of the project, an attempt was made to visits all sites of investigation at least three times. However some of these visits were fruitless due to weather conditions. This resulted in data for only two visits at certain sites. However this served the purpose of allowing the investigator to develop an understanding of the timing of the emergence of different dragonfly species.

The most important instrument in the capture process was indeed the aerial net. This capture process was difficult at first due to the fact that several of the species studied tended to fly at high altitudes. The most successful catching motion consisted of a long quick but controlled and graceful swing of the net followed by a covering of the net's mouth by flipping the sack - like portion of the net over the mouth. A forceful batting motion with the net would often result in the capture of an injured dragonfly or a complete miss. It was observed that the investigator employing the use of the aerial net was more successful at catching the dragonfly from behind rather than catching an oncoming insect , which found it easier to avoid capture.

Certain species of dragonflies flew especially close to the ground including the Ladona julia as well as the Gomphus spicatus. A special technique of capture was discovered for these dragonflies consisting of a dropping of the net upon the ground. Once the insect was captured, the net was pulled upward (with the mouth of the net remaining on the ground). In this way the insect flew to the backmost portion of the net so that I was able to fold the net over, preventing the release of the dragonfly.

The abundance of dragonflies in the air seemed to depend on the portion of the summer, time of the day, as well as (and most importantly) the weather. Due to the fact that the weather is such an important factor the abundance of dragonflies during the summer of 1992 was extremely poor. In fact, many of the research days in June were hindered by cold temperatures, rain, and lack of sun. It should be noted that only one of these charactersistics need exist to decrease flight of dragonflies drastically. It was absolutely incredible to note the extreme effects of sunlight upon the dragonflies. If the sun was simply behind a cloud for a few moments the dragonflies would quickly move to the vegetation of the area.

On those research days when the weather was conducive to dragonfly flight, the best hours for collecting were between 11:00 am and 6:00 pm. Very few insects would fly early in the mornings. This is especially true during the cooler mornings. However those that did fly were easier to catch as they flew closer to the ground, straighter and slower. The height of dragonfly abundance came between the hours of 1:00 pm and 3:00 pm. This portion of the day was usually the warmest and it was at this time that most of the insects were quick and agile in flight. Most dragonflies also seemed more able to sense the movement of the investigator at this time of the day. It was fairly easy to catch those dragonflies visible in vegetation during the morning hours as their reaction time was definitely longer than it was during the afternoon hours. During the evening there was a considerable amount of dragonflies as it is during this time that there is little breeze. This lack of wind is conducive to the flight of dragonflies. It also seemed that the evening was the time of the greatest mosquito abundance and this may have cause dragonflies to come out for their prey.

Due to the fact that the summer was an extremely cold and rainy one in the Upper Peninsula, this investigator believes that the cold affected the timing of the emergence process to some extent. In this way the cold water of the aquatic habitats may have caused the metabolism of dragonfly larvae to be lower than normal, and slowed the maturation process altogether. This would cause emergence of the species to be delayed. My hypothesis led me to experiment with the effects of cold on the dragonfly nymphs. This experimentation is to be included later.

Following the capture of the insect, I would remove the dragonfly from the aerial net by taking hold of its thorax (region directly below the head) and placing it quickly in the killing jar. Much care was used when opening this jar as the gas eminating from the solid is indeed potent and harmful. If inhaled, the gas tends to cause a burning sensation in the nostrils, in addition to nausea and a light headed feeling. Thus, the user shoud open the jar with its mouth facing out, place the dragonfly into the jar, and quickly cap the container (being careful not to let the dragonfly escape). The dragonfly should remain in the killing jar for a minimum period of time. The dragonfly should be dead before removing. However, the goal is to allow the dragonfly to retain as much of its natural color as possible. It is indeed true, as investigator Michael Fisk notes, in his survey of the Anisoptera at UNDERC during the summer of 1991, that by leaving the dragonfly in the killing jar for an extended period of time much of the coloration of the dragonfly is lost. Thus following a short containment in the killing jar, the dragonfly is removed and placed into a collecting jar until the investigator is able to return to the lab. Collecting jars are to be clean and free of chemical residue. However, I found that a paper towel in the collecting jar is benificial as it collects any moisture in the jar or on the insects themselves.

Upon returning to the lab, the insects were removed from their respective collecting jars and pinned for the purpose of straightening out the wings of the dragonfly. This was especially necessary for some of the smaller species of dragonflies as they were flimsy and difficult to handle. A different mounting board was utilized for each site of collection and these boards were labelled as to the date and spot of collection.

There was a certain technique utilized to pin the dragonfly properly to the board. First of all the board is adjustable so that the board can accommodate the width of the dragonflies' bodies. In this way, a pin is placed through the thorax of the dragonfly and this pin is pushed into the space between the adjustable boards. At this point the height of the dragonfly on the pin is adjusted in such a way that the boards are at the proper height necessary to spread out the wings in a parallel position to the body. The pinning of the wings is done with small strips of paper. A single strip of paper is pinned at both ends almost perpendicular to the actual wing so that only a small portion of the center of the strip covers the wing. With most medium size to large dragonflies two strips are needed for each wing so that the end of the wing does not curl.

Different procedures were utilized regarding the nature of the pinning procedure and timing of the photography. In some cases, photographs were taken only a couple of hours after being pinned. In other cases these dragonflies were allowed to stay overnight under the chemical hood (which served as protection from the bats and contained no chemicals) prior to photography. In some cases, the more colorful dragonflies were placed into the refrigerator overnight. In most cases beneficial effects of refrigeration were unobservable. However, in the case of those dragonflies with yellow coloration, such as Hagenius brevistylus ,it did seem that the refrigeration process helped the dragonflies to retain color for a longer period of time. Another attempt was made to retain color by sealing the dragonflies off from air overnight by covering the pinning boards with plastic wrap. No beneficial effects were observed. Finally several dragonflies were not pinned at all prior to photography. It was possible to work with some of the more flexible ones in an attempt to straighten out the wings and the bodies of the dragonflies. This allowed for the best retention of color for photography.

Following the photographing process, which is to be explained later, those who were not easily identifiable were looked at under a dissecting microscope and "keyed out" according to the family, genus and species keys provided by Merrit and Cummins in An Introduction to the Aquatic Insects of North America, and Walter and Corbet's The Odonata of Canada and Alaska (Volumes 2 & 3). Confirmation of species identificaton of the dragonflies common to the UNDERC property was done by taking a look at the photographs produced in prior years by Michael Fisk and Tim Piero.

Following the identification and photography processes each of the dragonflies were placed into cedar boxes and were organized according to family. Temporary hand-written labels were used at UNDERC. However, upon returning to the University of Notre Dame more professional typed labels were applied. When pinning these dragonflies it should be noted that the thorax of the dragonfly should be placed about three quarters of the way up on the pin. This is important as it allows the body of the dragonfly to dry on the pin properly. This investigator made the mistake of pinning the dragonfly too high on the pin in most cases. This is difficult to change because as the dragonflies dry out it is difficult to move them at all. Their bodies become rigid and delicate.

In the process of transferring the dragonfly collection from UNDERC to the University of Notre Dame campus in South Bend, Indiana some of the insect specimens were injured. Heads of certain insects detached from bodies as well as wings. This was discouraging to this investigator at first. However Dr. Martin Berg advised the use of clear nail polish. This acted as an adhesive substance and is barely noticeable when it dries.

Photography

Prior to research at UNDERC this investigator had no experience utilizing the Nikon FE2 camera or any other 35mm camera. This was definitely a disadvantage and made this portion of the project extremely difficult and costly. If it were not for the help of those tips given by Michael Fisk in his paper, **Anisoptera at the University of Notre Dame Environmental Research Center: Summer 1991**, it would have been most difficult to begin.

The biggest problem was obtaining quality photographs of the dragonflies with maximum color and minimum shadow. In order to have maximum color it was necessary to photograph shortly after capture. The problem early on in the project was lack of proper lighting. So, even though the colors in the dragonflies were great, this was not observable in some of the photographs.

Besides problems with coloration in the photographs, there was the ever-remaining problem of making the veination of the dragonfly wings visible. This is a very important component of the picture because it is nature of the veination which makes it possible to identify the species of a dragonfly. Obtaining photographs in which veination is clear was extremely difficult, especially if the wing had the slightest curvature. There was no way to focus on a curved wing.

The equipment used was the Nikon FE2 camera with the micro - NIKKOR 55mm lens (as was used by Michael Fisk). All of the pictures outside of a single set were brought to the Land O' Lakes Pharmacy who sent them the Foz Company for development. The developing was expensive but convenient, quick and quality. One set of pictures was brought to Ritz Photo Labs in Burlington, New Jersey for development.

The preparing of the dragonflies prior to photography is explained above. However it should be noted that an attempt was made to utilize a modified version of "Dr. D.A.L Davies' Low temperature dying method" which is referred to in Corbet's book, Dragonflies. In this method specimens are brought to the lab alive, allowed to evacuate their last meal, and cooled in the freezer. This method was somewhat successful in preserving colors in certain dragonflies. However, it was not possible to photograph these insects as they had not been pinned. Their wings were not flattened and time spent in the freezer made them much less flexible. Thus, in most cases, the insects were pinned and allowed to sit for a short period of time prior to being photographed.

As for a backdrop, a styrofoam board was used in most cases. Different paper was used to cover the paper at first. However it was found that those pictures with just the styrofoam background had better lighting and fewer shadows. This styrofoam background also made it possible to see much of the veination.

The main difficulty in the photography process was obtaining the proper amount of lighting. This investigator found the light from the ring flash to be insufficient, Thus, it was necessary to supplement this light with the small desk lamps used in the lab. Yet, I did find the light from the ring flash to be a significant importance as it helped to distribute the light evenly, eliminating shadows. One difficulty with the ring flash was that there was not step -up lens available which could attach the ring flash to the camera. This investigator traveled to several camera shops but this piece of equipment was not available. Instead, a thin piece to masking tape was used carefully to secure the ring flash to a nuetral filter which was screwed onto the lens. The film used was Kodakcolor Gold 200 as was used and recommended by Michael Fisk. One role of Ektar 100 film was utilized but this role did not develop.

In order to photograph the dragonfly, a pin (often already in the thorax) was pushed entirely through the dragonfly so that only the head of the pin was evident in the thorax of the insect. The lower portion of the pin was stuck into the thick styrofoam board so that the body of the dragonfly was sitting directly on the styrofoam. This made it possible to stabilize the dragonfly during the photographing proceedure. The camera was attached to its tripod which was secured onto a box, keeping the camera at a higher level. In this way the camera was looking straight down at the dragonfly. The lens was only a few inches away. A ruler was included in the first role of film taken. However it was discovered that this was more detrimental than beneficial to the pictures. First of all, it was an additional object needing to be focused. Also, because the rulers are made of plastic, they tended to reflect light and create a glare in the picture.

The most difficult part of the process was attempting to focus properly on the dragonfly. Sometimes this procedure would take close to a half an hour. Michael Fisk suggested focusing between the pairs of wings on the thorax. It was difficult to focus the head as well as the abdomen as both extremes tended to be lower that the region of the thorax.The shutter speed in all cases was set at 250. With the extra light provided by the dissecting lamps the light meter and the shutter pin came close to lining up. After focusing the photographs were taken. Usually three to four shots were taken of each specimen in the beginning of the summer in order to experiment with different lighting and focusing. Later in the summer two shots of each specimen were taken.

Mark Recapture

The Mark- Recapture experiment at the road between Plum Lake and Inkpot Lake was conducted on June 22nd and on June 23rd. Each day was split into three time intervals which included: 9:30am - 11:30am, 1:30pm - 3:00pm, and 3:30pm - 5:30pm. During the week prior to the experiment the other fourteen UNDERC students signed up to work one or more shifts so that for each shift three students were collecting. This group always included the primary investigator, Christine Ciervo.

Prior to the Mark - Recapture it was necessary to find if the marking element affected the mortality of the dragonflies. In this way thirty dragonflies were collected. Eighteen were of the species, Ladona julia while twelve were members of the species Gomphus spicatus. These dragonflies were split into two groups including an experimental group and a control group. Each group had an equal amount of dragonflies from each species. All members of the experimental group were marked by the blue Sharpie Fine Point Permanent Marker manufactured by Sanford. The markings were placed on the thorax. In the previous year the investigator marked the wings. However this investigator was concerned that such marking could impair the flight of the dragonfly. The blue marking was easily recognizable on the thorax. The marked dragonflies (the experimental group) as well as the unmarked dragonflies (the control group) were placed into respective styrofoam coolers with wire mesh. Within theses coolers was some vegetation (grass and leaves) as well as some lake water (taken from Brown Lake) which was placed into a finger bowl. A mass of cotton was placed in each bowl also. The dragonflies were observed at intervals for a twenty four hour period. None of the dragonflies died. It did seem that all of the dragonflies became much less reactive over a period of time. However this is not a significant result as the control group became inactive as well as the experimental group. As no differences were observed in the two groups of dragonflies it was assumed that the marking used is not toxic to dragonflies. If the marking utensil was toxic to dragonflies it would cause the population results to be distorted as those marked could die prior to the second day of the Mark Recapture.

On day one of the experiment the goal of the investigators was to collect all dragonflies visible and to mark those dragonflies who were of the species Ladona julia or Gomphus spicatus. All members of these species were recorded and marked with a the blue Sharpie permanent markers on the thorax. These dragonflies were then released. On the second day of the experiment it was the duty of the investigators to collect all visible dragonflies, to note and record those who were of the species Ladona julia and Gomphus spicatus, and finally to note and record whether or not the dragonfly had been marked. Before releasing the dragonflies they were remarked with the same Sharpie markers at a lower abdominal segment. This was to insure that a dragonfly was not captured and recorded more than one time.

The weather was very good on June 22nd (the first day of the experiment). Eighty members of the species Gomphus spicatus were collected and marked while thirty - eight members of the species Ladona julia were collected and marked.

On the second day of the experiment the weather was cooler and this was evident as there were less dragonflies in the air. In the final shift of 3:30 - 5:30 only one dragonfly was captured. However, the entire day's count consisted of thirty- seven members of the Gomphus spicatus (five of which were marked) and sixteen members of the Ladona julia (two of which were marked).

In order to estimate the population of a species in a certain area a probabilty equation is utilized: N = MC/R. In this equation M represents those dragonflies of a certain species caught and marked on June 22nd. C represents the total of dragonflies of the certain species captured on June 23rd. R represents the number of dragonflies recaptured on the 23rd that were marked. Finally N represents the population of the species in the region (in this case the 100 meter strech of road between Plum and Inkpot Lakes). For the species Gomphus spicatus the population estimate was 592, whereas for the species Ladona julia the population estimate was 304. All of this data is organized in **Appendix 1**.

There are many sources of error for this experiment. First of all it is very possible that the initial capture of the dragonflies on day one of the experiment caused injury. I saw this to be true in certain cases. This could affect the experiment in one of two ways. The marked injured dragonfly might remain unable to fly after capture and in effect make it more difficult for the investigator to capture the marked dragonflies. In a different way, injury could merely slow the speed of normal flight, making the marked dragonflies easier to catch.

In addition, it should be noted that although the effects of the marking element on mortality of dragonflies was tested, the effects of marking upon successful flying was not observable in the styrofoam coolers.

Finally the weather on June 23rd serves as a source of error in the experiment.

A second population Mark Recapture study was conducted in Bog Pot on July 19th and July 20th for on a single shift each day from 1:00pm - 4:00pm. Bog Pot is a shallow body of water approximately two meters deep. Due to this chest waders were worn by the investigator. This did not seem to inhibit the capturing technique due the great abundance of dragonflies in the region. The focus of the population study was the Libellula quadrimaculata. On the first day of the experiment sixty-nine dragonflies were marked. On the second day fifty-seven were captured. Two of these were marked. By plugging this figures into the fore-mentioned equation, an approximation of 1966 dragonflies of the classification Libellula quadrimaculata is determined. These results are included in **Appendix 2**.

Bionomic Knowledge

A total of twenty eight species were collected during the ten week research period. A list of these dragonflies, and the site and date of collection is included in **Appendix 3.** Newly discovered species include discovered species: Sympetrum atripes, Neurocordulia molesta and Leucorrhinia patricia

It was interesting to see different characteristics of different species of Anisoptera. It is important to note that one characteristic encompassing all species of dragonflies is the lack of flying behavior during the cold weather. Interestingly enough this was not exactly the same for those species of Zygoptera on the UNDERC property. In fact, damselflies were much more visible on the foliage than were dragonflies who must have hidden deeper in the vegetation.

A common prey of the dragonfly (in all stages of life) is the mosquito. From what was observed upon capture of hundreds of dragonflies, mouthparts were often occupied with adult mosquito bodies or larval mosquitos. This was to the advantage of the residents of UNDERC as they found some relief from the mosquito population during times of dragonfly emergences. Other prey of the dragonflies include black flies and midges.

Those dragonflies of greatest color, size and speed are the Aeschnids. Three species of the Aeshnidae family were collected. These include the Basiaeschna janata, the Epiaeschna heros, and the Gomphaeschna furcillata. However, it is important for me to note that the Anax junius was indeed observed at Bog Pot throughout the month of July. Although hours were spent in an attempt to capture this specific dragonfly this investigator was unable to do so. The greatest number of dragonflies belonging to this species which were observed at one time is two. This species had a habit of flying high, but it did occasionally dip down closer to the groud to survey the edges of the aquatic region. However, the Anax junius was too agile and quick for this investigator. In accordance with the areas in which the Aeschnids were collected (listed in **Appendix 1**), they seem to thrive in areas with a variety of vegetation including larger trees. No Aeschnids were found in swampy, or extremely marsh-like areas. As Michael Fisk asserts in his study of the Anisoptera the territory of these dragonflies is much larger than that of smaller and slower dragonflies. This is what makes capture so difficult. In most cases, since dragonflies are territorial, an investigator can remain in part of a dragonfly's territory and be sure that it wll return shortly. However, return takes much longer when the territory is extremely large.

Corduliids, were discovered early in the summer. Members of this family were present in a variety of habitats. The family consists of dragonflies of moderate sizes for the most part (except in the case of the Epitheca princeps). These dragonflies fly at fairly moderate heights and at moderate speed. As a result they were quite easy to capture. The first Corduliid was caputured on May 26th, and the last was captured on July 15th. Thus, they seemed to endure throughout the summer. This could indicate ongoing emergences.

The Gomphids were an extremely prevalent group at UNDERC. They were found in a great variety of habitats. However, this investigator noted most of them to be located in regions having some drier surrounding vegetation. In addition, it seemed that they were rarely flying directly over water. Members of the Gomphus spicatus were most often found in the grass, on the road, and in vegetation. In addition, it was noted that these dragonflies often flew close to the ground with only moderate velocity but short reaction time.

It is the Libellulidae family that wins the award for having the greatest number of species on the UNDERC property. The earliest species to be observed were the Libellula quadrimaculata, the Ladona julia, and the Nannothemis bella. Not only were the first two found early in the summer; they were prevalent throughout the summer. The Leucorrhinias seemed to emerged duringthe middle of the summer while those of the Sympetrum genus emerged close to the end of the summer.

It seems that the more moderately sized Libellulids fly wih moderate speed and tend to fly at moderate altitude as well. These dragonflies are found in a great variety of habitats including bogs, lakes, and marshy areas. The Leucorrhinias are much smaller in size and seem to fly at much lower heights, with less speed. They also seem to be more prevalent in bog-like areas. Finally those dragonflies of the genus Sympetrum are those which are the smallest of the dragonflies at UNDERC. This genus of dragonflies should also be noted for their late emergence. It is the Libellulids that I characterize as the most obviously territorial. Maybe this is due the fact that their territories were indeed small for the most part. The species I noted for its extreme territoriality is the Ladona julia. Members of this species seems to have an attraction to light (grey) colored wood. This included wood of trees and wooden paths. Often a dragonfly would remain at a certain spot on a branch of a tree for several minutes at a time. It would only move to chase away other dragonflies or to approach prey. Also noted for territoriality were members of the species Libellula quadrimaculata. These dragonflies are not as motionless for periods of time as are members of the Ladona julia. However, their territorial areas are small. The members of the Plathemis lydia should also be recognized for their strict territoriality. This species of dragonflies appeared late in the summer at Tenderfoot Creek. Across from the creekise a group of stones which serve as the territory for these dragonflies.

The fifth and final family of dragonflies known at UNDERC includes the Macromiids. Not many observations concerning this species can be drawn as only a single male member of this species was captured. It seems likely that they are rare on the UNDERC property.

Emergence

Although the synchronization of the emergence of the dragonfly population was observed by this investigor, an attempt to actually study the physical emergence process within the laboratory was unsucessful. However, this process was observed in the field. My observations seem to be consistent with Philip Corbet's assertion that the site for emergence is always close to shore. It seemed that for the most process began with the larva, removing itself from the water, and crawing onto some sort of raised vegetation. Here it would shed its final larval case and the fully developed wings would be visible. This is not to say that upon emergence the dragonfly would begin flight. In fact it seemed that upon emergence the wings of a newly emerged dragonfly were extremely wrinkled, making flight difficult. Thus, it seemed that the newly emerged dragonfly waited for some amount of time at its place of emergence.

It should be noted that in some cases the emerging dragonflies were not extremely close to shore. In fact they were on reeds rising from a body of water. A special case of this was observed at Firestone. However, this is not unusual as most of Firestone is a fairly shallow site. A larvae could crawl from floor of the aquatic region to the part of the reed which is raised outside of the water.

Larval Feeding Studies

First it seems important to specify that in order to maintain a constant within the experiment only one family of dragonfly larvae was used to study rates of consumption, effects of deprivation, and food preference. Larvae of the species Libellula quadrimaculata were collected from Ed's Bog. This served as the main source of dragonfly larvae as they seemed most abundant here. A single investigator could obtain close to thirty larvae in one and one-half hours at this single site, whereas at many other sites this investigator was not nearly as successful. The procedure by which the investigator would capture larvae consisted of the use of a delta net. The delta net was utilized to scrap under the mat of the bog. The investigator would then let the water drain from the net and she would finger through the contents of the delta net. In order to keep the larvae alive they were all placed into a single large jar which was half full of freshwater from Ed's Bog. This water had a pH of 5.5.

There were two major studies of feeding done. Results from both studies can be utilized in reference to rates of consumption, results of deprivation, and food preference. In study one eight groups of three larvae were utilized. The three in each group were labelled A, B, and C. The A larva of each group was fed a maximum amount; the B larva was fed a moderate amount, and the C larva of each group was fed nothing. In study one the mosquito larvae used for feeding included the Wyeomyia smithii , the Aedes trisereatus, as well as the Culiseta morsiteus. The Wyeomeyia smithii were obtained from fellow researcher Cindy Klechewski who collected them from pitcher plants at Tuesday Lake. The Aedes trisereatus were collected from the insides of the tires at the "Tire Dump" which is close to Tenderfoot Bridge on the way to Roach Lake. Finally the Culiseta morsiteus was obtained from the area surrounding Ed's Bog, in particular from under the walkway leading out to the central portion of the mat.

As far as manner and rate of consumption is concerned for members A and B of each group, it seemed obvious that upon feeding the larvae began to eat immeadiately. Only 1 of the 16 larvae fed had not eaten any of the mosquito larvae provided. This represents only 6.25 %. In addition the dragonfly larvae seemed to eat until satisfied during the initial feeding. In other words, their consumption was not staggered with interval between each mosquito larva eaten. Three might be eaten cosequecutively and at that point the dragonfly would refrain from eating and remain stationary.

The behavior noted seemed most interesting. Prior to feeding the larva seemed to be conducting a sequence of grooming behavior. The larva would rub its front legs together. It would stick its fore legs into the labium. Following the addition of mosquito larvae to the cup, the dragonfly larva seemed to head for the largest of the mosquito larva by following it very slowly and carefully. He or she would also positionn his or her head at the proper angle for easy capture. In a instant the larva makes a thrustful motion toward the prey and extends the labium. The mosquito larva (in a successful capture) is sucked into the dragonfly larva's mouth about three quarters of the way. The dragonfly then remains still for a period of five to ten seconds moving only the mandibles and the spoon in a alternating fashion. At this point the remaining portion of the larval mosquito is sucked in by the dragonfly larva. When finished with this process the dragonfly larva in most cases remains still for a moment prior to its next capture.

Experiment one also showed that by depriving the larval dragonflies of consumption they did indeed consume at a much higher rate than did those dragonflies that had been fed previously. After the initial feeding of members A and B, part C was deprived of any food until all larvae given to A and B groups were eaten. In this way, all members had no mosquito larvae available. It was at Feeding #2 that 100% of previously deprived dragonfly larvae ate more than the A and B members of each group. After a five hour period the C groups had eaten an average of 71.43% of the food provided for consumption. After this same five hour period groups A and B had eaten a total of 19.9% of the food provided at Feeding #2. After twenty hour period the C groups had eaten 89.3% of the food provided at Feeding #2, and groups A and B had eaten an average of 21.6%. These results are shown in **Appendix 4.**

They were a number of results obtained from experiment one that relate to the preference of the Libellula dragonfly larvae for certain species of mosquito larvae. For those larvae fed with both mosquitos of the species Aedes trisereatus and of the species Wyeomyia smithii, a definite preference for the Aedes trisereatus was noted. In fact, 66.67% of the Aedes trisereati (refered to as "Substrate 1" in Figure 5.1) supplied were consumed while only 5.0% of the Wyeomyia smithii offered to these same larvae were consumed. These results can be viewed in **Appendix 5.**

There were also a group of larvae fed only Wyeomyia smithii and Culiseta morsitei. In this case the Wyeomyia smithii was preferred. This is demonstrated as 66.71% of the Wyeomyia smithii population provided to the dragonfly larvae was consumed while ony 27.77% of the Culiseta morsiteus population was consumed.

Study two of Larval feeding is very similar in experimental design. However, more larvae were used and the experiment had a longer duration. Evenso, the results were virtually the same. In this way, deprivation of certain dragonfly larvae resulted in increased feeding of this larvae. One notable observation concerned a dragonfly larva which had been deprived food for a week's time. At the end of this deprivation period the larva was provided with more and more mosquito larvae until it halted consumption. The single dragonfly larva consumed seventeen mosquito larvae within a time period of two hours.

In this experiment the same preferences concerning species of mosquito larvae were observed. Yet, it was in this experiment that it was observed (to a much greater degree) the preference of the dragonfly for the largest mosquito larvae available (sometimes regardless of species).

Another important factor noted in this experiment was the detrimental affect that algal growth tends to have on the dragonfly larvae. Those larvae recognized for having some algal growth on their legs, abdomen and thorax reacted much more slowing to availability of food and tended to consume less than other larvae.

Temperature Effect on Larval Metabolism

To this investigator's dismay it seemed that the emergence of several species of dragonflies was delayed by the cold and unusual (for the season) weather. This fact made the study of the effects of cold on the metabolism seem to be an interesting route to pursue.

In order to conduct such and investigation two groups had to be put together. Both the experimental as well as the control group consisted of five dragonfly larvae. One Aeschnid was in each group, while the other four consisted of one larger and three smaller members of the Libellulidae family. The Aeschnids were collected at Tenderfoot Bridge by the main gate. The other larvae were obtained from Ed's Bog. Both groups were placed into square, one-half foot deep containers with a wire mesh secured to the top of the container. In each container was three-quarters an inch of water (collected from Ed's Bog) which was measured as having a pH of 5.23 in each case. In each container a certain amount of foliage was inserted. This consisted of leaves, sticks, and leaves from the area surrounding Ed's Bog The control group was kept at the normal outdoor temperature (in July) which was an average of 16.8 degrees Celsius during the experimental process. The experimental group was kept in the refrigerator. The temperature of the water throughout the experiment ranged from 7 degrees Celsius to 4 degrees Celsius.

The quantitative method which was utilized as a raw measurement of metabolism was the measure of consumption (of mosquito larvae). As far as the first feeding was concerned the control group consumed 93.75% of the food available (Aedes trisereatus and Wyeomyia smithii) while the experimental group consumed 50.0% of the food provided. Following this, over a forty-eight hour period the control group consumed the fifty mosquito larvae with which it was provided, while the experimental group only consumed ten. Outside of eating the fifty mosquito larvae provided the larger dragonfly larvae of the control group ate the three smaller larvae. This was significant as it may indicate that dragongfly larvae will first consume mosquito larvae as food, but will resort to eating members of its own family when other supplies have been exhausted. Additional studies should be done from this.

Finally one major observation which also suggests slowed metabolisms among the members of the experimental group is their slow movement upon observation. Members of the control group were very active, as they were constantly moving about the container. They were also very responsive to introduction of mosquito larvae. In contrast, those members of the control group were extremely still in their cold environment. Often movement could only be induced by touching them several times with forceps. At the end of the experiment the experimental group was removed from the refrigerator, and allowed to remain at the room temperature of the lab (approximately 16.8 degrees Celsius). These dragonflies began to move around in a fashion similar to those members of the control group.

The results of this experiment seem to indicate that the cold does indeed slow the metabolism of the larval dragonfly drastically. This makes it possible to hypothesize that this lowered metabolism can result in a delayed development which can in affect delay the emergence process.

The fact the the experimental group began to move around much more vigorously upon being exposed to normal temperature, and the fact that none of the organisms died may indicate that although the cold slows the maturation process, it does not permanently harm the dragonfly larva.

Acknowledgements

I wish to express my gratitude to Mr. and Mrs. Bernard J. Hank for making it possible for the UNDERC program to exist. My participation in this program made it possible for me to experience a unique "hand's on" approach to Aquatic Biology. I can not properly express my appreciation of the beautiful housing facilities and the richness of the environment itself. Next, I wish to thank Dr. George B. Craig for his insights, patience and helpfulness that he provided as my advisor. I admire his great enthusiasm for the world of insects, and specifically the world of dragonflies. Through him I have come to appreciate this area of biological study. He helped me to recognize the beauty of the insects that I once called "bugs". (I wasn't refering to Hemiptera either.) I would also like to thank Dr. Martin Berg for his advice and encouragement during the summer. I thank all of the UNDERC professors for introducing me to the world of Aquatic Biology. My appreciation also goes out to all of my classmates at UNDERC who helped me with my project and made the summer a most enjoyable time for me. I also find it necessary to mention that without the help of Edward T. Pierpont, I would never have been able to figure out how to work the camera properly. Finally, I wish to give a special thanks to Mr. and Mrs. Hellenthat, without whose help in returning to New Jersey I would still be stuck at UNDERC. (I am not sure that would be such a bad thing.)

Appendix 1

Table 1

Time of day	No. of Gomphus spicati Collected on Day #1	No. of Ladona juliae collected on Day #1	No. of Gomphus spicati Collected on Day #2	No. of Ladona juliae Collected on Day #2
9:30am-11:30am	27	12	16 **3marked**	4 **1marked**
1:30pm-3:00pm	27	9	21 **2marked**	12 **1marked**
3:30pm 5:30pm	26	17	0	0
Totals	80	38	37 **5marked**	16 **2marked**

The above table represents the results from the Mark-Recapture experiment performed at the road between Plum and Inkpot Lakes on June 22nd and June 23rd of 1992.

Table 2

Variable	Gomphus spicatus Population	Ladona julia Population
M	80	38
C	37	16
R	5	2
N	592	304

This table represents the values for the variables utilized in the equation N=MC/R which was used to estimate the population of the specified dragonflies at the Plum and Inkpot Lake Mark-Recapture Site..

Appendix 2

Table 1

Description	Day 1	Day 2
Collected	69	57
Marked	---	1

2.1This table is a representation of the results received in the Mark-Recapture Study conducted across the road from Bog Pot on July 19th and July 20th for a single shift each day of 1:00pm-4:00pm.

Table 2

Variable	Value for Libellula quadrimaculatapopulation
M	69
C	57
R	2
N	1966

2.2This table contains those values for the variables used in the equation N=MC/R which was used to estimate the population of the Libellula quadrimaculata at the site of the Mark-Recapture study (across from Bog Pot).

Appendix 3

Family	Genus/Species	Sex	Site/Date
Aeschnidae	Anax juncea	?	Bog Pot/July
	Basiaeschna janata	m.	Tend. Ck. 6/3/92
		m.	Brown 6/22/92
		m.	Tend. Lake 6/21/92
	Epiaeschna heros	m.	Plum/Inkpot 6/29/92
		m.	Plum/Inkpot 6/27/92
		m	Tend.Ck. 7/11/92
	Gomphaeschna furcillata	m.	Plum/Inkpot 5/30/92
		f.	Plum/Inkpot 6/29/92
Corduliidae	Cordulia shurtleffi	m.	Plum/Inkpot 6/29/92
		f.	Tend. Ck. 7/11/92
		m+f	Forest Serv. 6/11/92
		f.	Cranberry 5/27/92
		m.	Nansen 6/27/92
	Dorocordulia libera	m.	Brown 6/9/92
		m	Bolger 6/28/92
	Epitheca cynosura	m.	Brown 6/9/92
		m.	Research Lab 6/11/92

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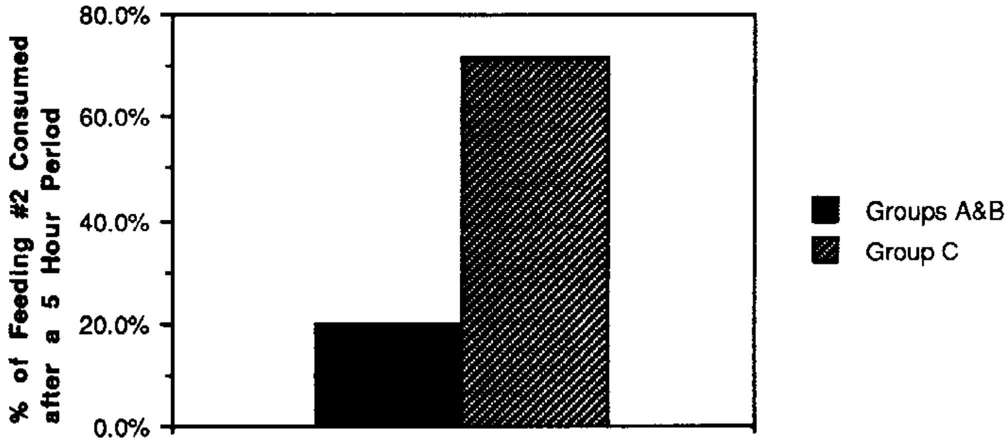
	Epitheca cynosura	m.	Tend lake 6/21/92
		f.	Bog Pot 6/2m+f
		m+f	Plum/Inkpot 6/22/92
		m.	Be[illegible]ner 7/19/92
	Epitheca princeps	m.	Plum/Inkpot 5/26/92
		f	Bog Pot 7/1/92
		m+f	Tend. Creek 7/15/92
		m.	Plum/Inkpot 7/15/92
	Neurocordulia molesta	m	Tuesday 5/30/92
Gomphidae	Gomphus cornutus	m.	Cranberry 5/27/92
		m.	Plum/Inkpot 6/20/92
	Gomphus exilis	m+f	Plum/Inkpot 6/29/92
		m+f	Studt.Housing late June-July
	Gomphus spicatus	m+f	Bog Pot 6/21/92
		m+f	Plum/Inkpot 6/22/92
		m+f	Studt.
Housing			late June-July
		m.	Brown 7/6/92
	Hagenius brevistylus	m.	Plum/Inkpot 6/30/92
		m.	Behind maintainence house 7/6/92
Libellulidae	Celithemis elisa	m.	Ed's Bog

		6/21/92
	m.	Plum/Inkpot 6/23/92
	m.	Bolger] 6/28/92
	f.	Ward 6/29/92
	m+f	Bog Pot 7/1/92
Ladona julia	m.	Tuesday 6/9/92
	m.	Brown 6/9/92
	f.	Ward 6/21/92
	m.	Ed's Bog 6/21/92
	f.	Cranberry 7/5/92
	m+f	Research Lab 7/11/92
	m+f	Firestone 7/14/92
Leucorrhinia frigida	m.	Cranberry 5/28/92
	m.	Bog Pot 6/11/92
	f.	Tenderfoot Lk 6/13/92
	m.	Nansen 6/27/92
	f.	Ed's Bog 7/5/92
Leucorrhinia glacialis	m+f	Ed's Bog 7/5/92
	f.	Bolger Bog 7/10/92
	m.	Tend. Creek 7/15/92
Leucorrhinia hudsonica	f.	North Gate 5/28/92
	f.	Plum/Inkpot 6/21/92
	m+f	Nansen 6/27/92

		f.	Bolger Bog 7/10/92
	Leucorrhinia intacta	m.	Nansen 6/27/92
		m.	Bolger 7/10/92
	Leucorrhinia patricia	f.	Cranberry 6/27/92
	Libellula pulchella	m.	Tend. Crk. 7/12/92
	Libellula quadrimaculata	f.	Bolger Bog 5/26/92
		f.	Tenderfoot Lk 5/26/92
		m.	Plum/Inkpot 5/28/92
		m+f	Bog Pot 6/11/92
		m.	Ward 6/26/92
		m+f	Firestone 7/14/92
		m+f	Bog Pot 7/16/92
	Plathemis lydia	m.	Ward 6/28/92
		m.	Tend. Creek 7/12/92
		f.	Tend. Creek 7/13/92
	(non -pruinose)	m.	Tend. Creek 7/15/92
	Sympetrum obtrusum	m.	Tuesday 7/1/92
		m.	Bolger 7/10/92
	Sympetrum atripes	f.	Tuesday 7/12/92
		m.	Tuesday 7/19/92
Macromiidae	Macromia illinoiensis	m.	Bog Pot 6/21/92

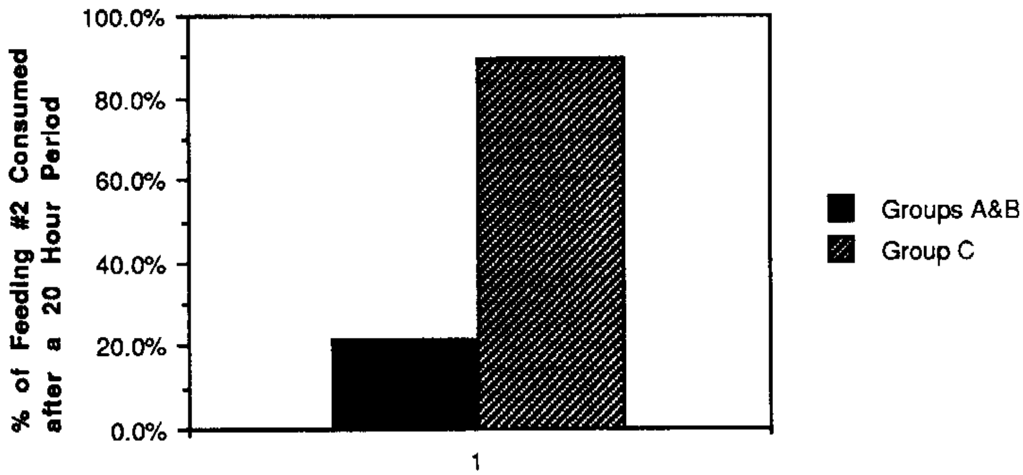
Appendix 4

Results of Larval Feeding Experiment #1



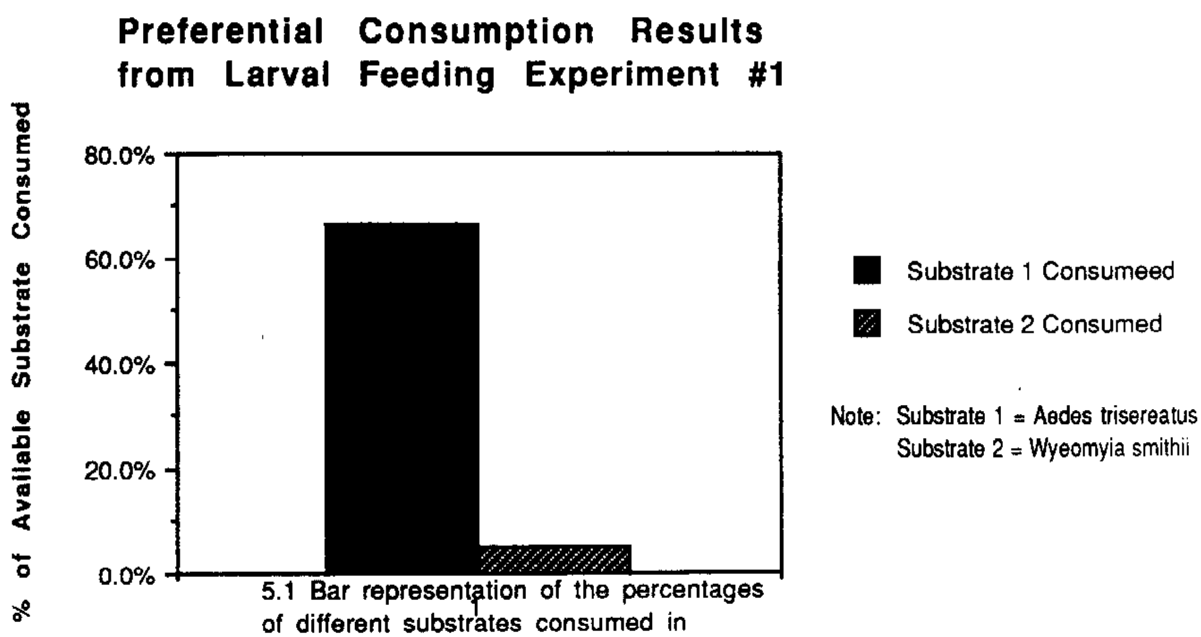
Graph 4.1 Bar Representation of Percent Consumption

Results of Larval Feeding Experiment #1



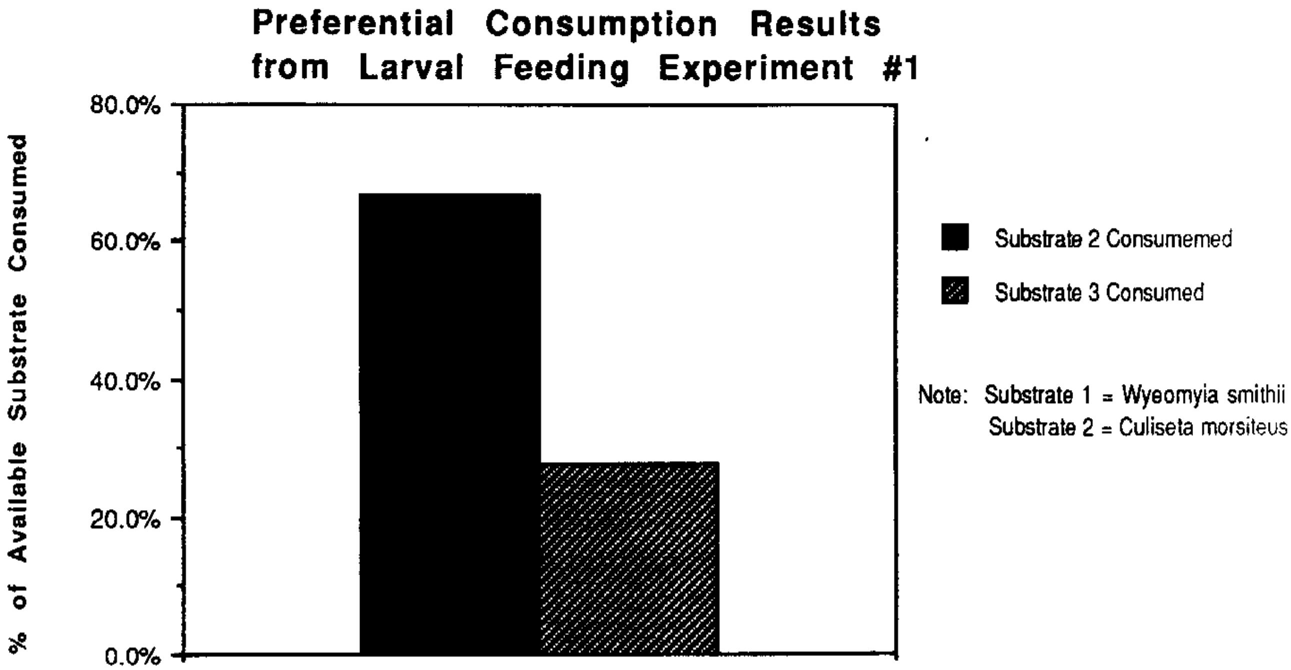
Graph 4.2 Bar Representation of Percent Consumption

Appendix 5



5.1 Bar representation of the percentages of different substrates consumed in Larval Feeding Experiment #1.

Appendix 5



5.2 Bar representation of the percentages of Substrates 1 & 2 consumed in Larval Feeding Experiment #1.

Checklist of the Anisoptera of UNDERC, Gogebic County, MI
Summers of 1987, 1988, 1990, 1991, 1992

Collectors: Chia, Ciervo, Fisk, Piero, Schuster
Advisor: Dr. George B. Craig, Jr.

Family Aeshnidae
- Aeshna canadensis
- Aeshna umbrosa
- Anax juncea
- Anax junius
- Basiaeschna janata
- Epiaeschna heros
- Gomphaeschna furcillata

Family Corduliidae
- Cordulia shurtleffi
- Dorocordulia libera
- Epitheca canis
- Epitheca cynosura
- Epitheca princeps
- Epitheca spinigera
- Neurocordulia molesta
- Somatochlora kennedyi
- Somatochlora williamsoni

Family Gomphidae
- Dromogomphus spinosus
- Gomphus cornutus
- Gomphus exilis
- Gomphus furcifer
- Gomphus spicatus
- Hagenius brievistylus
- Ophiogomphus aspersus
- Stylurus scudderi

Family Libelulidae
- Celithemis elisa
- Erythemis simplicicollis
- Ladona julia
- Leucorrhinia frigida
- Leucorrhinia glacialis
- Leucorrhinia hudsonica
- Leucorrhinia intacta
- Leucorrhinia patricia
- Leucorrhinia proxima
- Libellula luctosa
- Libellula pulchella
- Libellula quadrimaculata
- Nannothemis bella
- Plathemis lydia
- Sympetrum atripes
- Sympetrum costiferum
- Sympetrum internum
- Sympetrum obtrusum
- Sympetrum rubicundulum
- Tramea lacerata

Family Macromiidae
- Didymops transversa
- Macromia illinoiensis

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