

1990

**Dragonflies of the University of Notre Dame
Environmental Research Center
Gogebic County, Michigan**

by
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ABSTRACT

A survey of Anisoptera on the UNDERC property was conducted throughout the summer and 27 species were found in wide diversity of habitats. New species found in adult form on the property that were not reported by previous odontologists include *Aeschna juncea* (sp?), *L. frigida*, *N. bella*, and *O. aspersus*. Additionally, a mark-recapture study was conducted to gain an idea of dragonfly populations in a given locale.

INTRODUCTION

There is perhaps no single location or given region more conducive to the study of dragonflies than the University of Notre Dame Environmental Research Center (UNDERC). Located between Upper Peninsula Michigan and northern Wisconsin, UNDERC's boundaries encompass a wide variety of prime dragonfly breeding habitats that includes bog ponds and their surrounding mats, accessible and extensive swamp and marsh-like areas, lakes, parts of a creek that runs through the property, vernal ponds and clearings in forested areas. The wide variety of unblemished habitat-types facilitates and supports a diversity of dragonfly species found perhaps nowhere else. Approximately forty different dragonfly species have been collected at UNDERC (27 in the 1990 summer alone) during the summers of 1987, 88, and 90. Refer to the attached "Checklist of Odonata of UNDERC, Gogebic Co., MI" by collectors Schuster and Cheah and Appendix I. The state of New York has 120 dragonfly species while Ohio has 100 (Kellogg, 1908). The fact that UNDERC has forty reported species in a much smaller area (approximately 10,000 acres) is worthy of note. Furthermore, since UNDERC is almost completely untouched by humankind (an increasingly rare situation in today's world), one should be able to make valid observations of these dragonflies in their most natural state. For these reasons, UNDERC is the ideal locale in which to study dragonflies.

The objectives of my study were 1) to collect as many different dragonfly species as possible, 2) to bring collected specimens back to the lab as soon as possible for photographs before they lost their colors, 3) with forementioned pictures in hand, to create an illustrative manual that contains the dragonflies of UNDERC. (This manual will serve future students and faculty alike by precluding the need to search through lengthy keys in order to identify a given dragonfly specimen.), 4) while collecting specimens, to observe their behavior in natural habitat and thereby increase knowledge of those species involved, 5) to conduct a successful mark-recapture in order to gain an estimate of the size of dragonfly populations in a given area and, 6) as time permits, to collect as many different naiads from around the property. As many details as possible will be conveyed to the reader so as to make conducting certain elements of such a study (especially the photography and mark-recapture) easier, and perhaps more successful.

METHODS

The most important pieces of equipment in collecting dragonflies were an aerial net, killing jar(s) with ethyl acetate (do not spill on specimen) or potassium cyanide (careful!), and storage jars with some type of absorbent paper (paper towel or tissue work fine) to reduce moisture content in jars. Jars were labelled so as to remember where the specimens were collected. One note on the net: large-mouth nets make catching airborne dragonflies easier while smaller-mouthed nets with less excess netting are easier to use when pursuing dragonflies that fly low to the water (for example, the Leucorrhinias). Excess netting tends to get wet and heavy. The length of the handle should be comfortable to the user.

Furthermore, any future collectors may find it advantageous to carry a pair of hip waders, a dry pair of socks, canteen of water, insect repellent, food, and a recent

map of the property. The hip waders are especially worthwhile to have on seeping bog mats and in swampy, marsh-like areas, as they allow one to more successfully leave *terra firma*. Ideally, one would also carry a delta net and jars with ethanol (see below) for use in collecting naiads at each of the sites visited. However, one has only two hands and both may be needed to collect adults while walking on the roads between collecting sites. Furthermore, one, by now, is carrying a substantial amount of equipment. It may not seem like much, but after several miles of walking, the extra weight could cause fatigue. The extra weight and bulk of more equipment reduces the agility often times needed to capture some of the more elusive adults.

I found the best collecting times to be between 8:30-9:00 AM and 4:30-5:00 PM on warm, sunny days. The dragonflies on these days were most active (and hardest to catch) between 12:00 noon and 2:00 PM. Typically, it has been found that there are fewer dragonflies on cloudy, cool, or overcast days.

This individual tried to collect at each prospective site at least once throughout the four research weeks. The few number of species collected in the western part of the property did not seem to justify the amount of time I spent there in the first three research weeks, it seems. There are a few lakes, namely, Nansen, Cranberry, and Roach, and they should be sampled, but by and large this area is higher, and consequently, drier, providing less ideal dragonfly habitat. As a result, most of the collecting was done along the road system in this part of the property. Access to Nansen Lake was never found and consequently, no collecting was able to be done here. This could be a potentially promising site to find new species, as there is little/no information on the composition of its dragonfly population.

Ideally, one should like to survey a site at least twice in the summer in order to gain a rough idea of how species composition of a particular aquatic habitat changes from one

point in time to another. Some sites to be considered in such a survey, based on past relative success in collecting there, are Tender Bog, Donut Bog, Tuesday Lake, Ed's Bog, Bolger Bog, Beaver Bog, Forest Service Bog, North Gate Bog, Firestone, and Plum/Inkpot. Some potentially good sites include Moccasin, Hummingbird, Bergner, Nansen, and Raspberry Lakes (**Caution:** may need permission to get near some of these lakes).

After a day of collecting, pictures were taken as soon as possible. If the wings of the anesthetized dragonfly were flat enough, the specimen was mounted and the picture was taken. If the wings were not level enough, the dragonfly was pinned on a spreading board and placed in the freezer overnight. Pictures of the specimen were then taken later, after allowing the specimens to "defrost" at room temperature. The photography set-up consisted of a 35mm camera, tripod, ring flash, and one or two other small desk lamps for supplementary lighting. The ring flash was screwed onto the lens of the camera and the camera was set on the tripod. As for mounting the dragonflies for pictures, a pin was placed through the specimen and then the pinned specimen was put onto a piece of thin styrofoam. The styrofoam was placed vertically in front of the camera lens. The distance between the upright styrofoam and camera was adjusted by moving the camera to allow for proper focusing. It seems that best results are obtained by focusing on the dragonflies thorax and not other parts of the body. There are problems with this set-up that will be addressed later. Also, tips for better pictures will be given later.

Identification, labeling, and preparation for permanent storage were also done. Typically, I used Merritt and Cummins to identify the dragonfly down to Family. Walker's The Odonata of Canada and Alaska, Volumes Two and Three, were used almost exclusively to identify Genus and Species.

On several cloudy days, when there were few or no dragonflies visible, I undertook to collect naiads. The

principle equipment was a delta net, tweasers, and jars filled with 70% ethanol. Naiads could be obtained by pulling the net along the bottom or by scraping the edge of the bog mats in the bog ponds/lakes. Naiads would be picked out with the tweasers and then placed into the alcohol. Identification could then be done in the lab as time permitted. Principal reference sources for this identification were again Merritt and Cummins and Walker's The Odonata of Canada and Alaska.

The next part of this project consisted of conducting a mark-recapture on the property. The primary purpose of the mark-recapture was to gain insight into the numbers of dragonflies of a given species that can be found in a certain geographically defined area. In mark-recapture, a known number of dragonflies are marked and released into a given habitat. After a given amount of time, the odontologist goes back to the locale and collects. The ratio of unmarked to marked dragonflies can then be used to obtain a population estimate. Through such a study, a better idea of the relative abundance of species in this area will also be obtained.

There are certain assumptions that underlie the use of the Lincoln index. Among these, as listed by T.R.E. Southwood, are 1)marks do not affect the animal and are not lost, 2)marked animals mix with extant population after marking, 3)equal catchability of marked vs. non-marked, 4)population is closed throughout the sampling period, and 5)there are no births or deaths in the population during the time of study. In order to adhere as closely as possible to condition three, care was taken in marking specimens. The mark was large enough to see when actually holding the dragonfly, but small enough so that one could not tell from a distance whether or not a dragonfly was marked. Dragonflies that suffered harm as a result of their capture were not marked, and marked dragonflies that appeared unable to fly were not recorded in the list of successful mark-release's. The genus/species, sex, and time and location of capture were

all recorded for successfully marked dragonflies. Special note was made of successful recaptures: the above information was recorded in addition to the color marked on their wing. These successfully recaptured dragonflies were then marked with the current day's color.

The site for the mark-recapture portion of my study was the isthmus of land between and adjacent to Plum and Inkpot Lakes. The geography of an isthmus facilitated my mark-recapture by allowing capture and release of dragonflies from a relative single point and by providing an area with definite boundaries in which to work. Additionally, Plum/Inkpot was chosen as the work site because of the small volume of traffic (traffic typically unfavorably stirs up the dragonflies) and the closeness of the locale to base camp which made shuttling volunteer collectors easier. Other sites considered were Tenderfoot Bridge (too small, too much traffic, and not many dragonflies, at least at the time of preliminary investigation) and the bridge over Tenderfoot on the northern edge of the property (too far away).

With the help of collectors from the UNDERC class, dragonflies were marked for three consecutive days: Monday June 25, Tuesday June 26, and Wednesday June 27. Collectors captured and marked from approximately 10:30-12:30 in the morning and from about 1:15(30)-3:15(30) in the afternoon on these three days. A different set of colors was used each for each of these days. Purple and blue were used to mark those dragonflies captured Monday, green and red for those on Tuesday, and finally, black and brown for those on Wednesday.

RESULTS

A complete list of all the dragonflies collected during the 1990 summer, along with their respective collection sites and dates can be found in Appendix I. Fig. 1 displays how species occurrence changed during the summer. An important note is that the last day of observations was effectively July 12. Consequently, most of the bars in Fig. 1 end at the

middle of July. It is very possible that the life histories of these dragonflies extend beyond this date. A total of 27 different species belonging to five unique dragonfly families were collected during the four research weeks. Newly discovered species on the property (adult form) include: Anax junius, Aeschna juncea (sp?), Ophiogomphus aspersus, Leucorrhinia frigida, and Nannothemis bella. The Anax junius and Leucorrhinia frigida have been recorded in adjacent Berrien County, Michigan by E.J. Kormondy. Elizabeth Schuster reports having captured an Ophiogomphus, but the species identification of the specimen was not indicated. Two other species of Ophiogomphus, namely colubrinus and rupinsulensis have been found in Gogebic County by E.J. Kormondy so one is not able to say whether she caught an O. aspersus or not. Surprisingly, Nannothemis bella was not previously recorded by former UNDERC odontologists or by Kormondy. At UNDERC, it was found only at Beaver and North Gate Bogs. Only males were obtained at Beaver Bog. At North Gate Bog, males and females were present and the females were so differently colored from the males (yellow abdominal annuls vs males' powdery, pruinose blue) that I thought I had found an entirely new species. A Nannothemis bella naiad was found at Bolger Bog.

Disappointingly, only two members of the Aeschnidae family were actually captured during the summer, one near the research lab (6/30) and the other on the road between North Gate Bog and Mullahy/Ward (7/12). Aeschnids, beyond reach, were seen at Foggy and Pomeroy Lakes (7/9). One Aeschnid was observed expressing territoriality at Bog Pot (6/26). Aeschnids were observed feeding in early evening hours (about 9:00pm) at Firestone Lake on several occasions during the week of July 17-21. One week earlier, Aeschnids feeding in substantial numbers during early evening darkness were observed at Crampton Lake by Dr. Craig. It seems as if Aeschnids were observed more often during the twilight hours

than during daylight hours, the exact opposite of what one might normally expect.

The Aeschnids are perhaps the most challenging species of UNDERC dragonfly to capture. They are extremely strong fliers whose ability to change direction at an instant belies their high level of speed. Secondly, the Aeschnids I observed tended to fly at least several meters above the water or shoreline, occasionally dropping lower to grasp prey or to drive invading dragonflies out of their territory. At Foggy and Pomeroy Lakes, Aeschnids were flying about five to ten meters above the water and about ten meters out from the shoreline. Aeschnids were indeed present at these two lakes; these were perhaps two of the best sites for Aeschnids that I had the opportunity to observe during the summer. Whereas smaller dragonflies such as the L. quadrimaculata and Leucorrhinias were observed establishing territories over small lengths of shoreline (five meters or less), the Aeschnids seemed to be able to patrol many tens even hundreds of meters of shoreline as was the case with the Aeschnid at Bogpot on June 28. The fact that these dragonflies patrol such large areas demands extra patience from the person trying to capture them, as it may be several minutes before the dragonfly makes it back from its route to where the collector is standing.

The Cordulids were prevalent from late May through early July and were found over dry roads and near bogs and lakes. C. shurtleffi was observed at Cranberry on two separate occasions throughout the summer, at Plum/Inkpot during the mark-recapture week and at Foggy and Misty Lakes on July 9 (Appendix I). On more than one occasion, C. shurtleffi flew straight at the collector, making their capture relatively easy. They were the only species that had this odd tendency in flight, although on one occasion, a number of Epitheca cynosuras and E. spinigeras flew in substantial numbers around the collector in order to feed on the attracted flies. This occurred at the end of June on the newly expanded road

leading to the newer gravel pit. The Epicordulia princeps became readily present near the end of June and seemed to be building to a peak during the first weeks of July, before departure of the students from camp. Moreover, a good number were observed and caught at Plum/Inkpot during the mark-recapture week (6/25-6/29). Like the Macromia illinoiensis to be discussed later, these large dragonflies often flew at greater heights, beyond the reach of the collectors, pursuing and feeding upon clouds of gnats, flies, and other insects. In early July, they became prevalent on the northeastern part of the road immediately encircling the camp. Several E. princeps were observed flying over the grassy area immediately in front of the student residences. Whereas on good days there would be perhaps hundreds of E. cynosuras and spinigeras flying around, there would only be one or two accompanying E. princeps patrolling the upper reaches of these dragonfly hordes. E. cynosuras and spinigeras were prevalent in large numbers over much of the property. E. cynosura was largely found over dry roads adjacent to bodies of water (at Peter/Paul, Ward, Plum/Inkpot Lakes), but occasionally were found flying immediately near the lake edge (at Moosehead Lake) or farther from any body of water (on road west to Cranberry). The case for the E. spinigeras is very much similar to that of the E. cynosuras with the exception that once an E. spinigera was found at Forest Service Bog on June 13. Both the E. spinigera and cynosura are caught with relative ease due to their flight path predictability simply by approaching from behind after they have landed on the ground or on roadside vegetation.

Gomphus spicatus was as prevalent as either the E. cynosuras or E. spinigeras, it seemed. G. spicatus was found in large numbers over dry, sun-lit roads with the E. cynosuras and E. spinigeras. During the mark-recapture, there were several instances of G. spicatus being caught with food in its grasp, eating on the wing. In three instances, G. spicatus were found eating what appeared to be newly

emerged damselflies. They would eat hand-fed flies seemingly to no end while being held by the wings and/or thorax. They began by either chewing off or debilitating the head of the fly and then would proceed to devour the remaining entirety of the fly. This process took anywhere from thirty seconds to a minute depending on size of the fly and probably the appetite of the G. spicatus. In one instance, a G. spicatus was caught eating a L. intacta. One could say that G. spicatus are moderately aggressive feeders. Gomphus exilis was found almost exclusively very close to a body of water or actually flying near the edge of water. For example, two of these dragonflies were captured on the dock at Crampton Lake. These dragonflies were also obtained at Plum/Inkpot. G. exilis are aggressive feeders in nature. If offered a finger, it will promptly begin to gnaw with a vengeance greater than that of its larger relative, G. spicatus. Although it hurts no more than a pin prick, be aware lest you lose a good specimen simply by surprise. During the mark-recapture part of my experiment more than one person was surprised by the tenacity and endurance of the G. exilis and of Gomphids in general. Indeed, I found Gomphids to be the most aggressive feeders of all the dragonfly families on the UNDERC property. It is a matter of curiosity to me to determine whether or not O. aspersus and Hagenius brevistylus are as aggressive as these smaller Gomphids. Due to the apparent rarity of these species on the property, few actual observations were made of them in their natural habitat.

. The Libellulids were perhaps the most beautiful of the dragonfly families that I had the opportunity to work with. Celithemus elisa was often found flying over the bog mats (especially at Tuesday and Bolger), near bogs, and over the vegetation along the edges of lakes. C. elisas could also be readily found in the grassy field near the volleyball court adjacent to the student residences. This was the only non-aquatic area in which I found the elisas. Because of their low level and slow speed of flight, C. elisas can be caught

with supreme ease. On cooler, overcast days, C. elisas were one of the few, if not the only, dragonfly species that was out and about flying. On July 11, a particularly overcast, cool day, C. elisas were caught almost exclusively at both Bolger and Ed's Bogs. Few, if any, other species were captured that day. Had the weather been better, I would have expected to find more Leucorrhinias, and possibly Sympetrums along with the C. elisas, as they tend to inhabit some of the same areas of a bog.

Called "the workhorse of dragonflies" by Dr. Craig for its utility in mark-recaptures, Ladona julia is one of the most common species of dragonfly on the property. Though somewhat less common over bog-like and lake habitats, L. julia rivals in number G. spicatus, and E. spinigera over the road system at UNDERC. L. julias are not the easiest dragonflies to catch, and successful capture requires, at times, patience and a quick net.

The Leucorrhinias of UNDERC are very prevalent in bog habitats and marshy areas. It is difficult, if not impossible, to think of a bog that did not have Leucorrhinias. Conversely, there were only two or three circumstances in which I captured Leucorrhinias over dry land, away from water. One such circumstance was on July 12 in the eastern part of the property. Starting at the juncture in the road east of Tuesday Lake and proceeding northward from this point toward North Gate Bog, I obtained a good number of Leucorrhinia proximas and also Sympetrum internums. This seemed unusual for throughout most of the summer I had been collecting L. julias, G. spicatus, E. cynosuras and E. spinigeras over such dry areas. These two species would have been at the bottom of the list had I been asked to predict possible species at such a site. Perhaps some of the best non-bog-like habitats to collect Leucorrhinias, Sympetrums, and L. quadrimaculatas lie along the stretch of road between North Gate Bog and Mullahy/Ward. This entire northern-most loop of road on the UNDERC property is one undeniable

treasure trove for those odontologists willing to make the effort to get there and traverse its marshy expanse. For the UNDERC odontologist, the word "bog" should *immediately* conjure two words; the first word being Leucorrhinia for the above reasons, and secondly, diversity. Diversity being included for the simple reason that it was often possible to collect four or five, and sometimes more, different dragonfly species in substantial numbers at these bog habitats. I collected a total of five different species of Leucorrhinia throughout the summer. L. hudsonicas and L. proximas were the most abundant of these five. Usually when patrolling along the water's edge, Leucorrhinias would stay within about 120 cm of the water's surface and close to shore. Typically, they would alight upon the vegetation right at the bog's edge. One could then make substantial numbers of captures simply by sweeping a net through this reed-like vegetation. Leucorrhinias are easily driven away from their own territory by the much more aggressive and territorial L. quadrimaculatas.

At several sites including Forest Service Bog, Leucorrhinias could be seen caught in low-lying spider webs, from which I could extract them and consequently have relatively good specimens. L. intacta, easily identified by the yellow spot on its seventh dorsal tergite, was perhaps the hardest of the five to catch. Upon alighting on reedy vegetation, it would continually move its head around examining its surroundings for potential predators. None of the other Leucorrhinias seemed so cautious when resting and none of the others appeared in so few numbers as the L. intacta. L. intactas seemed more prevalent at Brown Creek on June 30 than at any of the other sites visited at any time throughout the summer.

Libellula pulchella and Perithemis lydia were both especially prevalent at the newer gravel pit and over the river bed at the base of the rock hill at this gravel pit. These two species are elusive, fairly unpredictable fliers

and are perhaps the largest of the Libellulids on the property. They are not easy to catch, especially near the river bed because of the near inaccessibility of the site. On occasion, L. pulchella and P. lydia were observed flying near and over sun-lit roads. When over dry land, L. pulchella is extremely wary. Upon sensing a disturbance from behind, it will fly twenty meters up the road before settling down or it may simply fly off into the woods immediately upon sensing danger. Both of these responses make capture of this beautiful species somewhat more difficult.

Libellula quadrimaculata was often found in grassy roadside clearings and to a lesser extent over the roads. Upon sensing disturbance from behind, L. quadrimaculata will just as soon fly directly into the woods as fly farther up the road. In addition to the newer gravel pit, L. quadrimaculata could be found in shallow roadside marshes. One site that was especially good was the swamp about midway along the road between North Gate Bog and Mullahy/Ward. Here, the territoriality of L. quadrimaculata could be easily observed because of access to the marshy area and because of the number of L. quadrimaculatas. Typically, they had little problem driving away the Leucorrhinias that sometimes happened into disputed airspace.

Nannothemis bella is easily the smallest dragonfly on UNDERC property. Male N. bella at North Gate Bog were found almost exclusively at the edge of the bog mat flying less than 30 cm above the water and displaying territoriality amongst males of its own species. The females were found at a distance of at least one or two meters from the water's edge. They flew no higher than ten to fifteen centimeters above the bog mat. Often, the best way to catch the females was to get on hands and knees and examine the bog mat closely. The coloration of the females allows them to blend in greatly with yellowish-brown backgrounds provided by the bog mats. In my experiences, I found no other dragonfly so well-suited to their particular habitat. The Sympetrums are

only slightly larger than the N. bellas but were common not only in roadside marshes where they would perch on tall, reedlike plants, but also on roadside ferns in drier areas. Among the best sights for the collecting of Sympetrums was the marshy area on the right hand side of the road going to Brown Lake. This small, marshy area had perhaps the greatest concentration of Sympetrums seen anywhere on the property. I easily collected upwards of twenty specimens in about fifteen minutes. Another good collection site was the road immediately circling main camp. Again, a favorite resting place was on the ferns along the road. Finally, significant numbers of Sympetrums were found on the road that runs north to North Gate Bog and then west to Mullahy/Ward and Morris Lakes. Genitalia are used to a very large degree in identifying the species of Sympetrum, especially in the case of the males. Refer to Walker's Dragonflies of Canada and Alaska.

Two members of the family Macromiidae, Didymops transversa and Macromia illinoiensis were found on the property. M.illinoiensis was indeed the more prevalent of the two, at least considering where and when I collected during the summer. Many M. illinoiensis were caught during the mark-recapture week at Plum/Inkpot and on two or three occasions were caught in tandem. These were not easy to capture as they tended to fly high overhead, presumably following clouds of flies/gnats buffeted by the relatively strong winds coming off Plum and going in the direction of Inkpot. The best opportunities to capture M. illinoiensis were when the winds from Plum Lake blew them low across the isthmus of land separating the two lakes. By standing on the isthmus with net ready, one stood a good chance of snagging these large dragonflies.

Mark-Recapture:

The mark-recapture portion of this experiment was carried out from June 25 through June 29. Approximately 360

dragonflies were marked on June 25, 26, and 27. (For a breakdown of numbers of individuals from specific species captured each of these days, refer to Table 1. Remember that purple/blue were used Monday; green/red, Tuesday; and black/brown on Wednesday.) A point to take into account when reading data for 6/27 and 6/29 out of Table 1 is that the recaptures are already taken into account in the overall male and female counts.

A total of nine marked dragonflies were recaptured during the course of this procedure. There were no recaptures on Monday or Tuesday. This initially caused some concern and prompted trials which will be discussed later. The first recaptures were obtained Wednesday, the third day of mark-recapture. Those recaptures were four G. spicatus marked purple (three males, one female), one blue L. julia (male), and one red L. julia (male). No marking was performed on 6/28 due to inclement dragonfly weather: strong winds and cooler temperatures than on any of the three previous days. One recapture, a male L. julia marked green, was obtained on this blustery day. Two recaptures were obtained the following day, one of these being a recapture of a recapture. The double recapture was a male G. spicatus marked blue and black. The other recapture was a male L. julia marked with black.

G. spicatus was the most frequently marked and recaptured dragonfly. Five of the nine recaptures obtained were G. spicatus, the other four being L. julia. Also, referring to Table 1, one sees the categories "Gomphids" and "Epicordulias". These categories include those specimens unable to be positively identified in the field. It was felt that a less precise, positive identification was better than an incorrect attempt. Throughout the course of the mark-recapture other species besides G. spicatus and L. julia three were marked. Some of these other species that were marked but not recaptured include C. shurtleffi, E. cynosura, E. spinigera, L. quadrimaculata, and even L. hudsonica.

Total hours spent collecting per day can be seen accompanying Table 1. Population estimates using the entire week's data for G. spicatus and L. julia, the only two species with recaptures, were also done and the results are shown in Table 2. Population estimates for these two species on a per diem basis can be found in Table 3. Estimates can not be calculated using the Lincoln index for species with no recaptures because one ends up with some defined number over 0, which is an undefined quantity. G. spicatus and L. julia are the only two species for which recaptures were obtained. Estimates using the Lincoln Index, variances in those population estimates, and standard errors were made in accordance with Southwood (Ecological Methods, p.97) and Smith (Ecology and Field Biology, p. 687) and can also be found in Tables 2 and 3.

DISCUSSION

If it were not for the fact that nine individual recaptures were made, I might have had to call this particular mark-recapture much less than a success. As previously mentioned, no recaptures were made until Wednesday. How is this significant? First of all, it indicates that the marked individuals are not as "equally catchable" as the non-marked dragonflies (pointed out by Dr. Cully, 6/24/90). Why are they not "equally catchable"? After their marking and upon their release, many of the dragonflies could very well have flown out of the mark-recapture area, not to be seen again. If this is true, these dragonflies cannot be as "equally catchable" as those uncaptured, unmarked dragonflies still in the area. Had the marked dragonflies been unaffected by their marking experience, one would have expected more of them to remain around the area and thus, be more subject to subsequent recapture. On the other hand, there were many instances in which dragonflies I had marked simply flew away from me to land ten to fifteen meters up the road. The fact that the

dragonflies could have left out of natural instinct might tell something about dispersal out of an area. Furthermore, it is questionable whether or not a dragonfly "remembers" its capture for any period of time.

Whether or not the marker is toxic to or has a negative affect on the dragonflies is highly questionable. After no recaptures had been made by the second day of the week, there was concern over these two questions. Consequently, a simple test was made. A number of dragonflies were collected, primarily members of those that had been collected in larger numbers at Plum/Inkpot on Monday and Tuesday. Those species were G. spicatus, L. julia, C. shurtleffi, and E. cynosura. Two aquaria were obtained and two members of each of these species were placed in each aquarium. All the dragonflies in one aquarium were marked on their hind, right-hand wing with the markers which had been used to mark the dragonflies in the field. The tops of the aquaria were covered with cloth towels. Marked dragonflies seemed to expire no more quickly than unmarked dragonflies, indicating that the marker was not necessarily toxic. Still, the effect of the marker on dragonfly survival in the wild is seemingly unknown.

In using the Lincoln Index, one must be careful to adhere to those assumptions outlined by Southwood in Ecological Methods. As many precautions as practically possible were taken to do this. As mentioned before, individuals visibly damaged or shaken up by their capture were not marked. Also, care was taken to see that the marks had no deleterious effects on dragonflies after their release. However, some conditions such as maintaining a closed population are impossible for the experimenter to uphold.

According to the Lincoln Index, the population estimate (N) is equal to the total number of dragonflies marked (T) "in the pre-census period" multiplied by the total number dragonflies captured in the "census period" divided by the number of recaptures (Ecology and Field Biology, p. 687). In

the second and third days of the week, marking and recapturing were done at the same time. As such, there was no "pre-census" period per se. In my calculations based on the entire week's data (Table 2), Monday, Tuesday, and Wednesday were considered "pre-census" days because on any of the following days, recaptures could theoretically be obtained. Tuesday, Wednesday, and Friday were considered "census" day due to the fact that part of the intention, in addition to marking unmarked dragonflies, was to record specifically any previously marked dragonflies. Monday was not included because it was the first day of marking and there were not yet any marked dragonflies to be had.

The population estimate of G. spicatus in this locale for the entire week was 5,871. The extremely large upper limits of variance found throughout the data are largely attributable to the low number of recaptures (r). Had more recaptures been made, lower variances would have resulted. The standard errors represent 95 percent confidence levels. For example, the standard error for the value 5,871 was found to be 2,548. Thus, the investigator is 95 percent sure that the actual population size is somewhere between 3,323 and 8,419 dragonflies; that is, 5,871 +/- 2,548 dragonflies. Ideally, it would seem that one would prefer to have narrower confidence bands in order to gain a more precise idea of how many dragonflies there actually are.

Photography:

The most difficult part of this summer's work was obtaining decent photographs of collected dragonfly specimens in accordance with the forementioned goal of creating an illustrated manual of UNDERC dragonflies. Without the help of Mrs. Ronald Hellenthal and Dr. Martin Berg at UNDERC, little progress would have been made in this direction. Hopefully, the following pointers will help anyone trying to work with a camera for the first time, especially if that someone is attempting to photograph dragonflies.

Before jumping in, make sure that you have 35mm, ASA/ISO 64, color **print** film. This probably sounds ridiculous, but unless you check for sure, you may receive a small surprise when slides instead of the expected prints arrive. Surely, slides can be made into prints with no damage to the slides, but there are two problems. First, this requires extra time, money, and effort and secondly, slide film can be more difficult for the beginner to work with. The problem deals with a gadget called the *f/* (f-stop) setting. When using print film, the photographer can be three to four f-stops off the ideal and still obtain a good photograph. With slide film, however, the photographer can only be one or two f-stops off the ideal and still expect to obtain a good photograph. Due to the smaller margin of error, it can be even more difficult for a beginner to get a decent photograph. Consequently, unless one wants to specifically have slides, I would recommend using print film.

Another difficulty one should be aware of is distance of the dragonfly from the background on which it is mounted. If the dragonfly is too close to a lightly colored or white background, chances are that it will be dark in the photograph. The colors of the dragonfly will be lost in the larger amount of "white" light that is reflecting off of the background and into the camera lens. Also, details of the dragonfly will be hard to discern. Though I did not do this, I would recommend, if possible, devising a mount that holds the dragonfly a given distance away from the background.

Inside of the camera given by Dr. Craig are two small bars that are black and green. These can be seen along the left hand side while looking through the viewing lens. In order for these arrows to be "activated" one must pull the rewind lever out halfway, as if rewinding after a picture. Next, the shutter release should be pushed down until a small red light can be seen through the view lens. Practice this with no film: it is very easy to inadvertently snap a picture. Next, these two bars need to match before taking a

picture. The setting of the green bar represents the speed of the film; that is, how long the aperture will be opened during the shutter release. Throughout my work, this was set at 125, meaning that the aperture was open for 1/125 second. The setting can be adjusted by turning the circular knob on the top, right-hand side of the camera labeled "A" through "8" with a wide range of numbers in between. The black bar is made to more precisely match the green bar by adjusting the f-stop. The f-stop can be found directly behind the focus on this camera; it is responsible for the size of the aperture and consequently, the amount of light that falls on the exposed film.

Before taking a picture of a dragonfly in front of a lightly colored background, place a neutrally colored piece of paper (like a manilla envelope) in front of the background and adjust the two bars so they meet. Then remove the neutral background and, making no further adjustments except for focusing, snap the picture. I emphasize "no further adjustments" because in all probability, the two arrows will not meet after the neutral is removed. Barring other unforeseen circumstances, one should then obtain a properly exposed photograph. Adjusting the bars to meet while centered on the white background often results in over or under-exposed photographs. In overexposed photographs, the wings of the dragonfly are typically barely discernible, while in underexposed situations, the entire picture is darker than normal.

Try though I might, I was never completely able to eliminate all of the background shadows with my set-up at UNDERC. Consequently, I worked to minimize their effect.

With the addition of some means to hold the dragonfly away from the background and with the use of the neutral tones to set the specifics, I believe that my set-up (described in Methods) could potentially produce good photographs. However, the only way to find out for sure is to test these methods.

NOTE: Additional pictures were taken in the weeks following UNDERC using a tripod-mounted Bellows camera, chosen by many photographers for such work because of its ability to focus more effectively on small objects. Before any pictures were taken, a neutrally-colored placard was placed in front of the styrofoam and the specific adjustments as previously described were made. Next, the pinned specimen was placed on the styrofoam and picture was taken. The background was lighted by two blue lamps which seemed to have the effect of reducing shadows and minimizing the amount of light bouncing off the styrofoam, thus making the thorax and abdomen of the dragonfly more visible.

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I would like to extend the most sincere of thanks to Mr. and Mrs. Bernard J. Hank not only for their financial support, but also for their extended hospitality. Next, I would thank Dr. Craig for showing me the door to a new and fascinating world, the world of dragonflies! Never have I been fascinated with something so very worthwhile for so long! His advise, support, and transportation to remote and exotic collection sites on and off the property were all greatly appreciated. It has been an honor and a pleasure to be one of his advisees. A special thanks to Dr. Martin Berg whose advice on everything from Dermistidae to photography to prime UNDERC dragonfly habitat was invaluable in the implementation of this effort. To Dr. Cully and Dr. Holly, whose recent statistical advice allowed me to bring finishing touches to my dragonfly mark-recapture. And finally, many thanks to the following people:

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Dr. John Olive, Professor of Biology at the University of Akron, whose advice and guidance throughout my high school and college years has been truly valued. I can only hope to fully repay him by some day extending the same kindness to someone else who is trying to find their way.

John Carozza, for his unique contributions to my dragonfly collection and for the use of his weather data.

Fig. 1. Occurrence of Adult Dragonflies; UNDERC 1990.

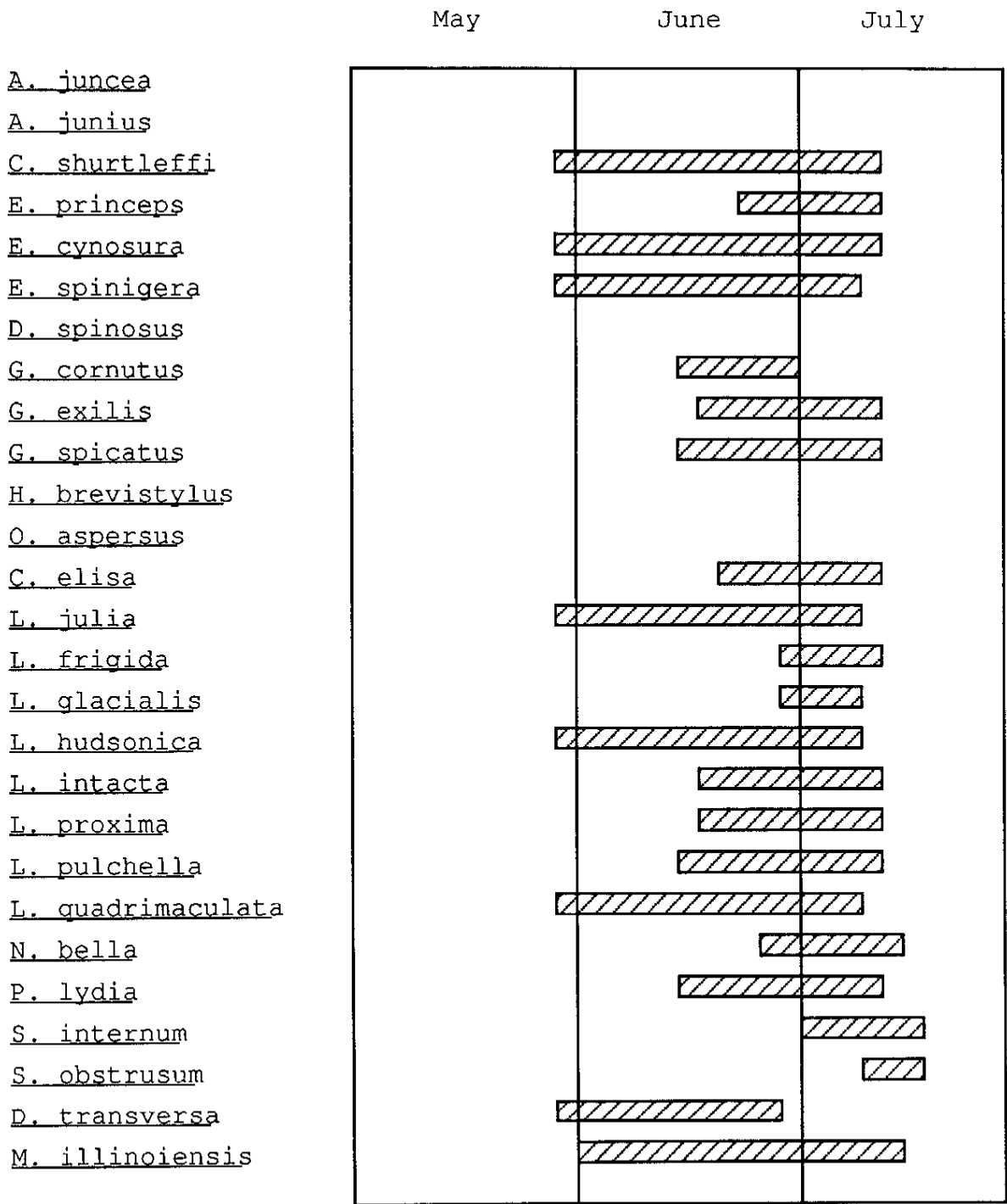


Table 1. Results of Mark-Recapture, UNDERC 1990.

6/25	Male	Female	Recaptures
<u>G.spicatus</u>	52	6	
<u>E.cynosura</u>	25	2	
<u>L.julia</u>	13	3	
<u>C.shurtleffi</u>	4	3	
Gomphids	5	0	No recaptures.
Epicordulias	1	0	
<u>L.quadrimaculata</u>	0	1	
<u>L.hudsonica</u>	1	0	

Collection times: 10:30-12:30 6 people hours
 1:15-3:45 4.5 people hours
 Total: 10.5 people hours

6/26	Male	Female	Recaptures
<u>G.spicatus</u>	55	15	
<u>L.julia</u>	20	5	
<u>C.shurtleffi</u>	1	8	No recaptures.
<u>E.cynosura</u>	6	0	
Gomphids	6	0	
<u>E.spinigera</u>	2	0	

10:30-11:15 1 person
 11:15-12:30 3 people
 1:45-3:30 3 people
 Total:9.75 people hours

6/27	Male	Female	Recaptures
<u>G.spicatus</u>	49	10	3 purple males 1 purple female
<u>L.julia</u>	27	7	1 blue male 1 red male
<u>E. cynosura</u>	4	0	0
Gomphids	15	2	0
<u>L.quadrimaculata</u>	0	1	0

10:30-12:30 3 people
 1:30-3:30 3 people
 Total: 12 people hours

Table 1 continued.

6/28 No marking done due to inclement weather.

One recapture: green male L. julia

6/29	Male	Female	Recaptures
<u>G.spicatus</u>	24	4	Male with blue, black
<u>E.cynosura</u>	3	0	0
<u>E.spinigera</u>	8	0	0
<u>C.shurtleffi</u>	0	2	0
<u>L.julia</u>	1	4	Male with black
<u>L.quadrifasciata</u>	1	1	0

9:57-11:54 approximately 2 hours

Table 2. Population estimates for G. spicatus and L. julia
Using Entire Week's Data.

	Pop. Est. (N)	Var N	St. Error
<u>G. spicatus</u>	5871.8	6.67*10	+2548
<u>L. julia</u>	1600.0	8.13*10	+883.9
<u>E.cynosura</u>	--	--	--

Table 3. Population Estimates for G. spicatus and L. julia
Using Data Per Diem.

	<u>WED</u>			<u>FRI</u>		
	N	Var N	St. Error	N	Var N	St. Error
<u>G.spicatus</u>	1888	830,720	897	5236	2.64*10	5128
<u>L.julia</u>	697	228,616	466	375	112,500	336.6

APPENDIX I. Dragonflies Collected at UNDERC; Summer 1990

<u>FAMILY</u>	<u>GENUS/SPECIES</u>	<u>SITE</u>	<u>DATE</u>
Aeschnidae	<u>Aeschna juncea</u>	N. Tenderft. Bridge	7/12
	<u>Anax junius</u>	Research Lab	6/30
Corduliidae	<u>Cordulia shurtleffi</u>	Cranberry L.	5/30
		Mn.Road: Ward to Camp	6/11
		Cranberry L.	6/12
		Mn.Road West of Tenderfoot Creek	6/14
		Foggy L.	7/9
	<u>Epicordulia princeps</u>	Plum/Inkpot	6/25
		Plum/Inkpot	6/29
		Near Student Res.	7/4
		Near Student Res.	7/10
	<u>Epitheca cynosura</u>	Observed as early as	5/28
		on main road east of Tenderfoot Creek	
		Brown L.	6/6
		Peter/Paul	6/7
		Ward L	6/12
		Mn.Road: Ward to Camp	6/12
Mn. Road West of Tenderfoot Creek		6/15	
Road West to Cranberry		6/15	
Plum/Inkpot		7/2	
Moosehead L.		7/9	
<u>E. spinigera</u>	Road east to Inkpot	5/28	
	Road to Long L.	5/28	
	Ward L.	6/12	
	Student Residence	6/12	
	Road between Bay/Long	6/13	
	Road near Bergner/Bay	6/13	
	Forest Service Bog	6/13	
	Main Road North of Roach	6/14	
	Western Part of Property	6/15	
	Plum/Inkpot	6/29	
Pomeroy L.	7/9		
Gomphidae	<u>Dromogomphus spinosus</u>	N.Tenderfoot Bridge	7/90
	<u>Gomphus cornutus</u>	Mn. Road West of Tenderfoot Creek	6/11
Mn. Road between Ward and Camp		6/11	
Gravel Pit (out of use)		6/29	

		Brown Creek	6/30
	<u>Gomphus exilis</u>	Main Road West of Tenderfoot	6/14
		Plum/Inkpot	6/27
		Brown L.	6/30
		Foggy L.	7/9
		Crampton L.	7/11
	<u>Gomphus spicatus</u>	Main Road between Ward and Camp	6/11
		Main Road West of Tenderfoot Creek	6/14
		Roads farther west than Main road	6/14
		Plum/Inkpot	6/27
		Plum/Inkpot	6/29
		Road to Roach L.	7/9
		Pomeroy L.	7/9
		Bolger Bog	7/11
		Road between Tuesday and North Gate Bog	7/11
	<u>Hagenius brevistylus</u>	N. Tenderfoot Bridge	7/9
	<u>Ophiogomphus aspersus</u>	Main Road West of Tenderfoot Creek	6/15
Libellulidae	<u>Celithemus elisa</u>	Tuesday Bog	6/18
		Plum/Inkpot	6/25
		Beaver Bog	6/26
		Donut Bog	6/26
		Plum/Inkpot	6/27
		Beaver Bog	7/6
		Brown L.	7/6
		Foggy L.	7/9
		Misty L.	7/9
		Bolger Bog	7/11
		Ed's Bog	7/11
		North Gate Bog	7/11
	<u>Ladona julia</u>	Road to Inkpot	5/28
		Marsh near Forest Service Bog	5/30
		Road to Cranberry	5/31
		Brown Lake	6/6
		Main Road between Ward L. and Camp	6/11
		Student Residences	6/12
		Peter/Paul	6/13
		Road to Cranberry	6/15
		Beaver Bog	6/26
		Foggy L.	7/9

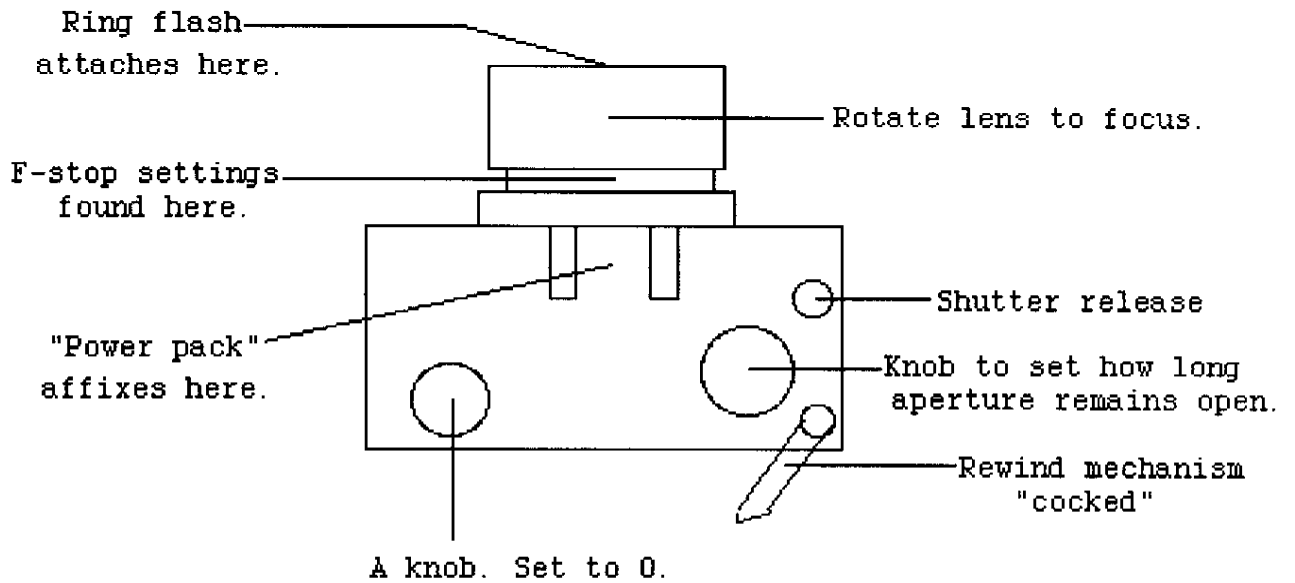
	Road to Roach L.	7/9
	Big Lake	7/11
<u>Leucorrhinia frigida</u>	Gravel Pit	6/29
	Misty L.	7/9
	North Gate Bog	7/12
<u>Leucorrhinia glacialis</u>	Forest Service Bog	6/28
	Tender Bog	7/11
<u>Leucorrhinia hudsonica</u>	Road near Long L.	5/28
	Cranberry L.	5/31
	Road to Cranberry	6/15
	Western part of property	6/15
	Marshy area	6/15
	Beaver Bog	6/26
	Donut Bog	6/26
	Misty L.	7/9
	Foggy L.	7/9
<u>Leucorrhinia intacta</u>	Brown Creek	6/15
	Beaver Bog	6/26
	Forest Service Bog	6/28
	Brown Creek	6/30
	Pomeroy L.	7/9
	Gilbert L.	7/11
<u>Leucorrhinia proxima</u>	Swampy, marsh-like area	6/15
	Western part of property	6/15
	Tender Bog	6/20
	Donut Bog	6/26
	Gravel Pit	6/29
	Brown Creek	6/30
	Foggy L.	7/9
	Misty Lake	7/9
	Road between Tuesday and North Gate Bog	7/11
<u>Libellula pulchella</u>	Main Road from Ward to Camp	6/11
	Plum/Inkpot	6/25
	Gravel Pit	6/29
	Gravel Pit	7/9
	Pomeroy L.	7/9
	Gilbert L.	7/11
	Palmer L.	7/11
<u>Libellula quadrimaculata</u>	Main Road East of Tenderfoot Creek	5/28
	Main Road from Ward to Camp	6/11
	Road West to Cranberry L.	6/15

	Road West to Crampton	6/15
	Plum/Inkpot	6/29
	Pomeroy L.	7/9
<u>Nannothemis bella</u>	Beaver Bog (no females)	6/26
	North Gate Bog	7/12
<u>Perithemis lydia</u>	Western Part of Property	6/14
	Gravel Pit	6/29
	Gravel Pit	7/9
	Gilbert L.	7/11
<u>Sympetrum internum</u>	Road near Camp	7/2
	Swamp along road on way to Brown	7/11
	North Gate Bog	7/12
	Road between Tuesday and North Gate Bog	7/12
	Bridge over N. Tenderfoot Creek	7/15
<u>Sympetrum obstrusum</u>	N. Tenderfoot Creek	7/8
	Marshy area south of UNDERC North Gate, close to Mullahy	7/9
Macromiidae	<u>Didymops transversa</u>	Road east to Plum/Inkpot
		Plum/Inkpot
		5/28
		6/28
	<u>Macromia illinoiensis</u>	Roach L.
		5/30
	Marsh near For. Service	5/30
	Plum/Inkpot	6/25-6/29
	Latest date	
	(site questionable)	7/9

APPENDIX II. Naiads Collected at UNDERC; Summer 1990.

<u>FAMILY</u>	<u>GENUS/SPECIES</u>	<u>SITE</u>	<u>DATE</u>
Aeschnidae	<u>Aeschna canadensis</u>	Ward L.	6/6
	<u>Aeschna mutata</u> (or <u>canadensis</u>)	Morris L.	6/18
Corduliidae	<u>Cordulia shurtleffi</u>	Tuesday L.	5/22
		Ed's Bog	6/6
		Bolger Bog	6/28
	<u>Epitheca canis</u>	Tenderfoot L.	7/3
	<u>Epitheca cynosura</u>	Ward L.	6/6
Gomphidae	<u>Gomphus spicatus</u>	Tenderfoot L.	7/3
	<u>Ophiogomphus</u> <u>rupinsulensis</u> (possibly <u>carolus</u>)	Bolger Bog	5/22
	<u>Ophiogomphus</u> <u>rupinsulensis</u>	N. Tenderfoot Ck.	7/16
Libellulidae	<u>Ladona julia</u>	Raspberry L.	6/6
		Bolger Bog	6/28
		Tenderfoot L.	7/3
	<u>Celithemus eponina</u>	Tuesday L.	5/22
		Peter/Paul	6/6
		Bolger Bog	6/28
	<u>Leucorrhinia glacialis</u>	Bolger Bog	5/22
		Ed's Bog	6/6, 6/28
	<u>Leucorrhinia hudsonica</u>	Ed's Bog	6/28
	<u>Leucorrhinia proxima</u>	Kickapoo	6/28
	<u>Libellula luctuosa</u>	Marsh near Forest Service. Date (?)	
	<u>Nannothemis bella</u>	Bolger Bog	6/28
<u>Pachydiplax longipennis</u>	Raspberry	6/6	
<u>Perithemis tenera</u>	Peter/Paul	6/6	

Appendix III. Top View of 35 mm Camera With Various Parts Labelled.



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