# FISH PREDATION ON ODONATA LARVAE

BIOS 569 -- Practicum in Aquatic Biology

Megan E. Glah

University of Notre Dame
204 Lewis Hall
Notre Dame, IN 46556

Ronald A. Hellenthal

M. Sean Dunlap

1999

ABSTRACT:

Dragonflies, belonging to the order Odonata, are a primitive group of insects. There are approximately 5000 living species of dragonflies today, and over 80 have been identified on the UNDERC property. Fish act as the keystone predators of dragonfly larvae in benthic environments, but are usually not present in acidic lakes. The purpose of this study is to determine the behavioral responses of odonates to the presence of fish. To do this, tanks are divided in half by hardware cloth and a small sunfish is placed on one side of the tank. The spatial response of larvae in the tanks will be observed. Additionally, habitats without fish will be sampled for larvae to determine the structure of the odonate communities. No conclusive results for the anti-predator responses of the dragonflies were obtained because the fish killed and/or ate too large a number of larvae. It is notable, though, that a significantly greater percentage of larvae from a habitat containing fish were able to survive than the larvae from a fishless habitat at each point in time during the experiment. The dragonflies from the habitat with fish may have survived at a greater rate due to the evolution of the slower, cryptic life-style. The larvae from the fishless habitat may utilize the faster, more aggressive life-style, thus evoking more attention from fish. This difference in life-strategies suggests that dragonflies do not exhibit a behaviorally plastic response to predators. The three dominant species of odonates in most lakes are Ladona julia, Leucorrhinia glacialis, and Cordulia shurtleffi. Ladona julia is uncommon in acidic habitats, but Leucorrhinia glacialis is extremely abundant.

Fish Predation on Odonata Larvae

INTRODUCTION:

Dragonflies, belonging to the order Odonata, are a primitive group of insects that is characterized by an aquatic larval stage and the possession of wings with complex venation and no wing-folding hinge. There are approximately 5000 living species of dragonflies today, and over 80 have been identified on the University of Notre Dame Environmental Research Center (UNDERC) property, located in Gogebic County, MI and Vilas County, WI. Dragonflies are important in aquatic habitats, serving as the dominant invertebrate predators of many aquatic insect larvae and as the prey of fish. Acting as opportunistic feeders, dragonflies take advantage of whatever prey is abundant and available to them (Miller 1987).

Predacious fish are believed to assume the role of keystone predators in many benthic environments, thus largely determining the species composition and abundance in odonate communities (Johnson and Crowley 1980). Predation by fish apparently restricts dragonfly naiads to one of two life-styles. These species-specific life-styles include a slower, cryptic, slow-growing type and an active, larger, rapid-growing type. Johnson and Crowley (1980) suggest that the search strategies employed by odonates in a particular habitat is associated with the risk involved in exposure to fish predators. The cryptic dragonflies are referred to as "sit-and-wait" odonates because they rely on tactile detection of prey in order to avoid attracting the attention of fish. This tactic is employed in habitats with the presence of fish predators. In habitats where fish predation is not a large concern, dragonflies adopt an active searching strategy that relies heavily on vision This response is due to a change in species composition and not on behavior plasticity.

Johnson (1991) suggests that these behavioral differences among odonate species are evolutionary adaptations for coexistence with predators. Johnson cites an experiment in which dragonflies from a fish-free lake were found to be more vulnerable to predation by fish than dragonflies of the same species known to coexist with fish. The behavior of the two species also differed in response to simulated fish-attacks. The dragonflies from lakes with fish became motionless and 'played dead', but the dragonflies from the fish-free lake tried to escape the predator, behavior likely to elicit further attack. The findings of McPeek et al (1996) agree with these results. They found that damselflies from habitats without fish swam away from attacking predators, whereas species from habitats with fish as the top predators did not swim away from attacking predators.

Johnson (1991) found that in the laboratory, dragonfly activity was reduced by more than seventy percent in the presence of fish in comparison to no-fish controls. Dragonflies obtained from a fishless habitat, however, showed no such response in foraging behavior. Another laboratory experiment cited by Johnson (1991) found that odonates from fish-free habitats were consistently more vulnerable to fish predation than those from lakes with fish. Most of the surviving odonates were those that naturally coexist with fish. Another important control in the structure of odonate communities are the direct and indirect effects of lake acidity. Carbone et al (1998) suggest that increases in the abundances of Odonata at pH below 5.5 are associated with the absence of fish predators as an effect of acidity.

In this experiment, tanks are separated in half by a piece of hardware cloth with a small sunfish on one side. Dragonfly larvae added to the tanks were expected to move through the hardware cloth away from the fish to the empty side of the tank. Additionally, fishless habitats were sampled to ascertain the make-up of the odonate communities. The purpose of this study is to determine the behavioral responses of odonate larvae to the presence of fish. The relationship of the structure of the communities to the pH and presence of fish were assessed and used to draw conclusions about the effects of fish predators on dragonfly naiads.

## MATERIALS AND METHODS:

Twelve glass aquariums were divided in half by a hardware cloth partition and the bottom of each tank was covered with pre-sifted sand. Each tank was aerated by securing an air stone to the hardware cloth partition. The tanks were filled with water from Tenderfoot Lake on the UNDERC property.

Twelve small (range approximately 50-70 mm) sunfish (Lepomis) were obtained from minnow traps placed throughout the shores of Morris Lake, located on the UNDERC property. The fish were chosen such that they were expected to be small enough that they could not eat the dragonfly larvae. One fish was placed on one side (determined randomly) of each tank. The fish were placed in the control tanks to rule out the possibility that the dragonflies were responding to chemicals emitted by the fish rather than to the presence of the fish themselves.

Twenty-four hours later, the fish were removed and 72 Ladona julia larvae from Bay Lake (a lake with fish, also located on the UNDERC property) were added to the tanks (6 in each tank). The larvae (Fi F-1 instar) were selected such that they were expected to be large enough that the fish would not be able to eat them. One fish was returned to each of six tanks (determined randomly). These were the six fish tanks. The other six tanks each had six larvae, but no fish. These were the fishless tanks. The experiment was run for seventy-two hours, and the number of larvae occupying each side of the tank for each replicate (1-6) and each treatment (fish and fishless) was recorded ever twenty-four hours. The experiment was then repeated with Ladona julia larvae from Bog Pot Lake, a fishless lake.

Five fishless habitats on the UNDERC property were sampled for a two-hour time period using D-frame dipnets to collect odonate larvae. These sites include Hummingbird Bog, Ed's Bog, Tender Bog, North Gate Bog and Trout Pond. The collected specimen were preserved in 95% ethanol solution and identified to species using Hilsenhoff (1995).

## RESULTS:

Figure 1 shows the average percentage of dragonfly larvae on each side of the tanks at 24, 48, and 72 hours for the fishless groups in the experiment. After 24 hours, there were an average of 44% of the larvae on side A and 56% on side B. After 48 hours, there were an average of 54.5% on side A and 45.5% on side B. At the conclusion of the experiment, after 72 hours, there were an average of 53% on side A and 47% on side B. The dragonflies in the fishless tanks all survived for the entire length of the experiment, suggesting that the dragonflies in the fish tanks were being eaten, not just dying off. Further evidence for this was that the fish were observed eating the dragonflies in the tanks.

The survival rates of naiads in the experimental tanks (those with the fish) are presented in Figure 2. Of the Ladona julia larvae from Bay Lake (a habitat with fish), 58.3% survived for 24 hours, 30.6% for 48 hours, and 22.2% for 72 hours. Of the larvae from Bog Pot Lake, the

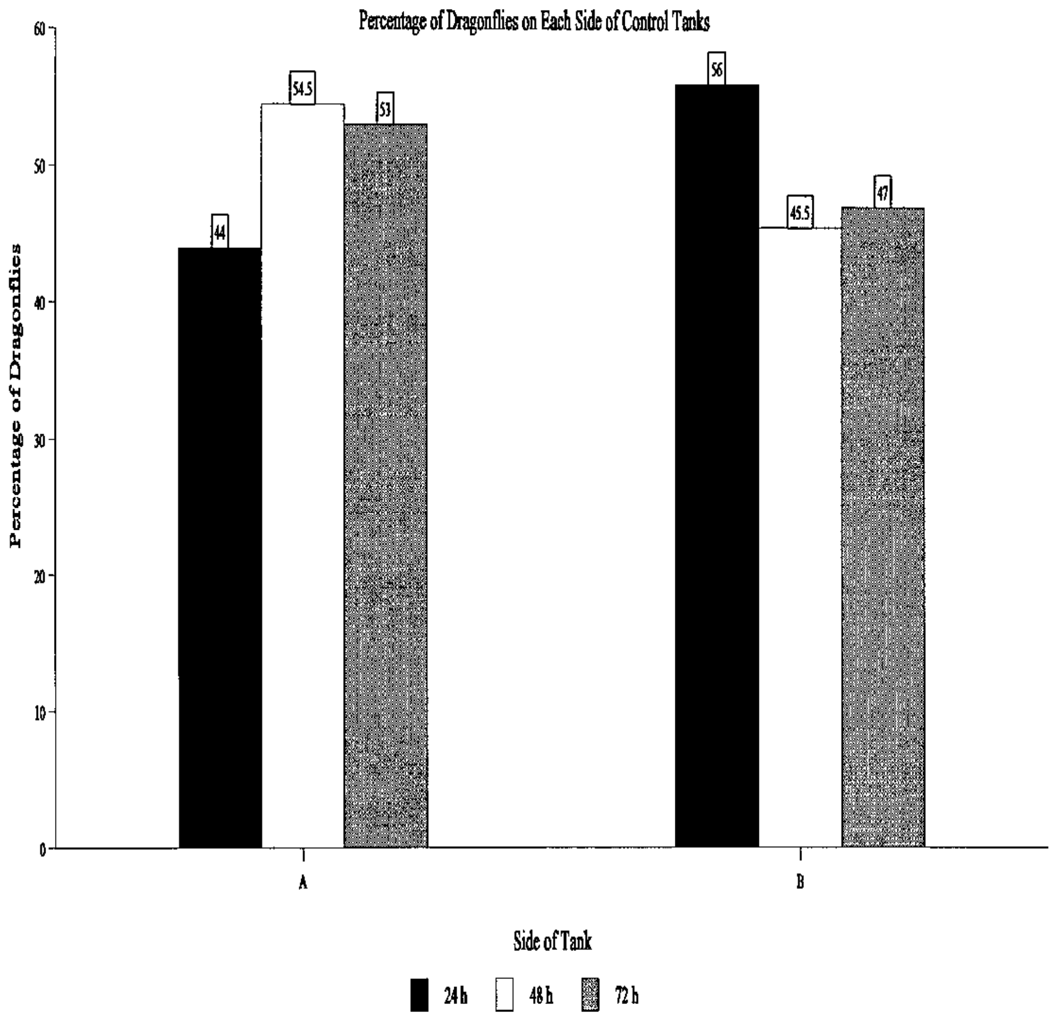


Figure 1: Average Percentage of Dragonflies on Each Side of Control Tanks After 24, 48, and 72 Hours. There is no significant difference in the percentage on each side for any period of time (p=0.481 ).

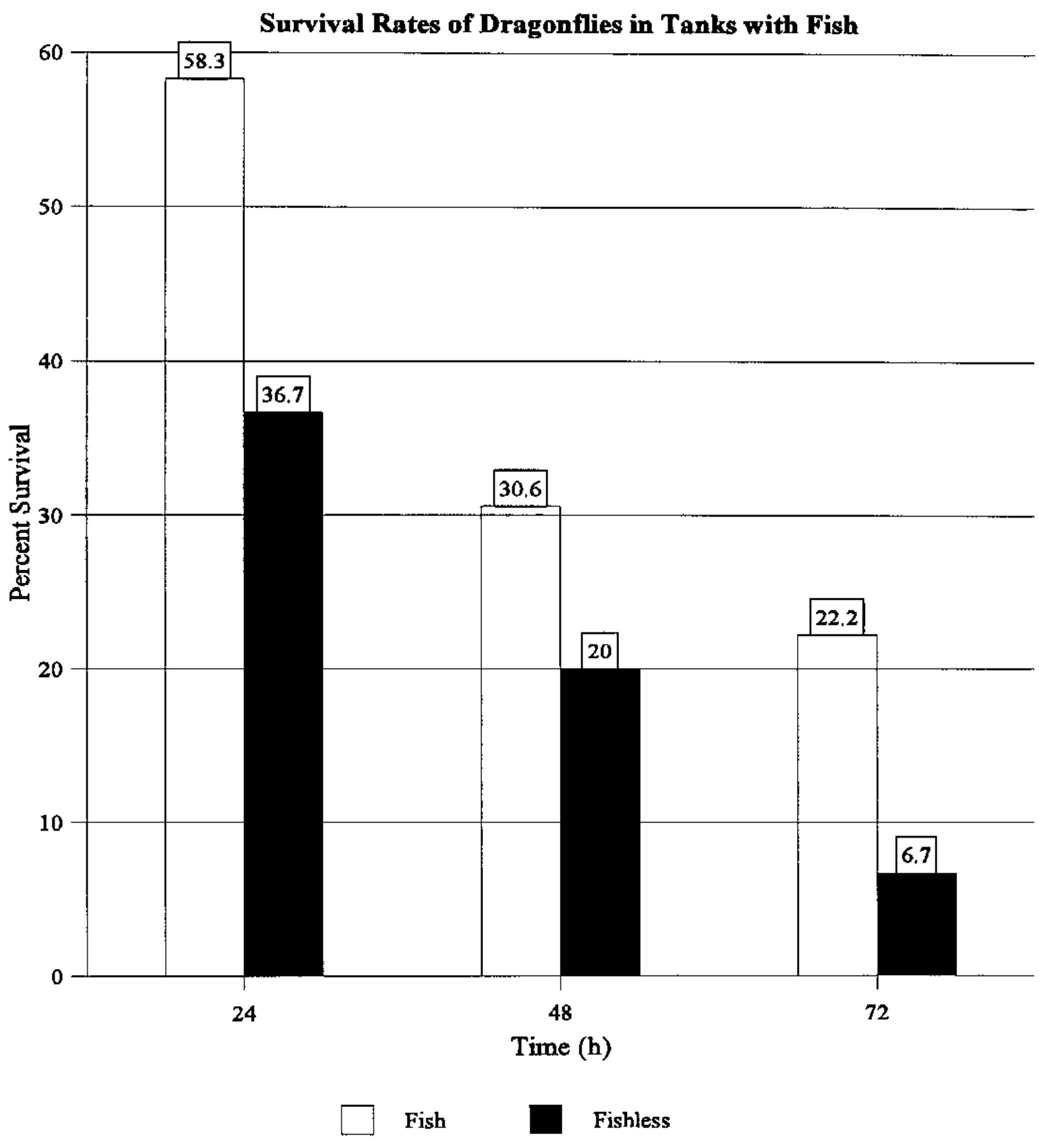


Figure 2: Survival Rates of Dragonflies (*Ladona julia*). The survival rates of the larvae from the fish habitats were significantly higher than those of the larvae from fishless habitats. This may be a indicative of the anti-predator behavior of the two different life strategies.

fishless habitat, 36.7% survived for 24 hours, 20% for 48 hours, and 6.7% for 72 hours.

The results of the collections of odonate samples were compiled and the total number of Odonates collected from each of the five habitats are shown in Table 1, as well as the species distribution of the samples from each site.

DISCUSSION:

Figure 1 shows that dragonflies, in the absence of fish, can be expected to distribute themselves relatively evenly across an open area such as the aquariums used in this experiment. Thus, any difference in the percentage of larvae on each side of the experimental tanks should be attributable to the presence of the fish. No conclusive results for this were obtained, however, because the fish killed and/or ate too large a number of the larvae. The small sunfish were not expected to be capable of eating the large dragonfly larvae, but this assumption was incorrect. The fish succeeded in eating a large portion of the dragonflies in each experimental tank. In a study by Martin et al (1991) the diets of sunfish were inspected to determine their impact on the population density of odonate larvae. These sunfish, *Lepomis microlophus*, consumed large numbers of dragonflies and, in an experiment, produced a statistically significant reduction in the number of larvae.

It is notable, though, that a significantly greater percentage of larvae from a fish habitat were able to survive than the larvae from the fishless habitat at each point in time during the experiment. The dragonflies from the habitat with fish may have survived at a greater rate due to the evolution of the slower, cryptic life-style previously discussed. The larvae from the fishless habitat may utilize the faster, more aggressive life-style, thus evoking more attention from the fish. Fish tend to strike more at active larvae compared to inactive larvae. This increased attack rate suggests a conflict between antipredator behaviors. Swimming is an appropriate response to avoid predation when dragonfly larvae are the top predators, but is dangerous when fish that cue in on movement are nearby (Baker et al 1999). Therefore, dragonflies from a fishless habitat that are adapted to this swimming response are in more danger than dragonflies from a habitat with fish present because those dragonflies have evolved the strategy of hiding or remaining still in the presence of predators.

In a study by Bendell and McNicol (1995), they report that Odonata larvae tend to be more plentiful in benthic samples from fishless lakes than from lakes with fish, and their exuviae are significantly more numerous around the fishless lakes. They found the three dominant species in most lakes to be Ladona julia, Leucorrhinia glacialis, and Cordulia shurtleffi. In most acidic fishless lakes, however, Ladona julia is uncommon and Leucorrhinia glacialis is extremely abundant. Another study by Suhling (1999) reports that in field experiments carried out to study the effects of fish predation on groups of larval dragonflies, the densities of small sized larvae inhabiting cages are reduced in the presence of fish compared with fish-free controls.

The findings of this study are consistent with the above results. In fishless habitats, Ladona julia accounted for none of the 624 individuals collected. Leucorrhinia glacialis, however, made up 192 of the individuals and Cordulia shurtleffi accounted for another 77. Only 66 larvae were collected from the 8 UNDERC habitats that contain fish in a separate study (E.A. Buescher, unpublished data). This difference is likely due to the presence of fish in these lakes.

Odonate Species Collected from Fishless UNDERC Habitats

| | Ed's Bog | Hummingbird Bog | North Gate Bog | Tender Bog | Trout Pond |
|---|---|---|---|---|---|
| L. glacialis | 133 | | 58 | 1 | |
| C. shurtleffi | 31 | 3 | 3 | 12 | 28 |
| A. junius | 1 | | | | |
| L. congener | 7 | | | | 1 |
| L. intacta | 1 | | | | 1 |
| N. irene | 3 | | 2 | | |
| C. resolutum | 1 | 0 | 1 | | |
| S. vicinum | 0 | 11 | | | 26 |
| L. frigida | | 16 | 29 | | 45 |
| Aeshna sp. | | 2 | 3 | | 5 |
| Somatochlora sp. | | 1 | | | |
| A. umbrosa | | 4 | | | |
| N. pentacantha | | 1 | | | |
| L. hudsonica | | | 18 | 149 | |
| N. bella | | | 2 | | |
| L. dryas | | | | 1 | |
| D. libera | | | | | 11 |
| L. quadrimaculata | | | | | 1 |
| E. canis | | | | | 10 |
| S. rubicundulum | | | | | 1 |
| A. subarctica | | | | | 1 |

Table 1: Odonate Species Collected from Fishless Habitats at UNDERC. A total of 177 larvae were collected from Ed's Bog, 38 from Hummingbird Bog, 116 from North Gate Bog, 163 from Tender Bog and 130 from Trout Pond.

Fish Predation on Odonata Larvae

The high acidity of the fishless habitats excludes fish from successfully reproducing. According to the findings of S.R. Carpenter (UNDERC, unpublished data), Ed's Bog has a pH of 4.2, Hummingbird Bog has a pH of 4.7, North Gate Bog has a pH of 4.8, and Tender Bog has a pH of 4.2. These acidic habitats do not support fish, and as a result, have an abundant population of odonates. Hummingbird Bog shows a lesser abundance of dragonflies, based on the collections of this study, than do the other habitats sampled. This difference could be due to a small population of stunted yellow perch that live in the bog. Nearby Bay Lake is operated by a lowland isthmus from Hummingbird Bog and fish migration may be possible due to spring flooding (UNDERC, unpublished data).

One problem with the setup of this experiment may be that the dragonflies were not capable of recognizing that the other side of the hardware cloth was a safe zone from the fish. There was no vegetation or habitat similar to the natural lake placed in the tank, that the larvae would be capable of recognizing as a natural hiding place from the predator. Ryazonova and Mazokhinporshnyakov (1993) found that the pattern of spatial distribution of larvae was modified significantly in the presence of predatory fish in the experimental tank, such that the larvae appeared less frequently in the unprotected spaces without aquatic plants. This protection behavior of the larvae was based on the hydrodynamic detection of the predators andc the modification of spatial distribution of larvae remained after the fish were removed. The results of that study indicate that if natural protection was placed in the tanks, the dragonflies may have recognized it and been able to elude the fish. The effect of such a change could be studied in future experiments.

ACKNOWLEDGMENTS:

The writer wishes to acknowledge the source of funds for the course, The Bernard. J. Hank Family Endowment, and to thank Sean Dunlap for his guidance and expertise on the subject of the study. This research would not have been possible without the endowment or the use of the UNDERC property and its resources. Additional recognition should be given to the members of Team Odonata and of the UNDERC class of 1999 for their help and support throughout this project.

REFERENCES CITED:

Baker, R.L., C.M. Elkin and H.A. Brennan. 1999. Aggressive interactions and risk of fish predation for larval damselflies. Journal of Insect Behavior 12: (2) 213-223.

Bendell, B.E. and D.K. McNicol. 1995. Lake Acidity, Fish Predation, and the Distribution and Abundance of Some Littoral Insects. Hydrobiologia 302: (2) 133-145.

Carbone, J., W. Keller and R.W. Griffiths. 1998. Effects of changes in acidity on aquatic insects in rocky littoral habitats of lakes near Sudbury, Ontario. Restoration Ecology 6: (4) 376-389.

Hilsenhoff, W.L. 1995. Aquatic insects of Wisconsin. Keys to Wisconsin genera and nots on biology, habitat, distribution, and species. Natural Hist. Council, Univ. Wisc. - Madison, Publ. No. 3.

Johnson, D.M. 1991. Behavioral Ecology of Larval Dragonflies and Damselflies. TREE vol. 6, no. 1.

Johnson, D.M. and P.H. Crowley. 1980. Odonate "Hide and Seek": Habitat-Specific Rules? Chapter 49 In: (Kerfoot, W.C., ed.), Evolution and Ecology of Zooplankton Communities. University Press of New England.

Martin, T.H., D.M. Johnson and R.D. Moore. 1991. Fish-mediated alternative life-history strategies in the dragonfly Epitheca cynosura. Journal of the North American Benthological Society 10: (3) 271-279.

McPeek, M.A., A.K. Schrott and J.M. Brown. 1996. Adaptation to predators in a new community: Swimming performance and predator avoidance in damselflies. Ecology 77: (2) 617-629.

Miller, P.L. 1987. Dragonflies. Cambridge University Press, New York.

Ryazanova, G.I. and G.A. Mazokhinporshnyakov. 1993. Effect of the presence of fish on spatial distribution of dragonflies larvae, Calopteryx splendens (Odonata). Zoologichesky Zhurnal: 72 (3) 68-75.

Suhling, F. 1999. Effects of fish on the microdistribution of different larval size groups of Onchogomphus uncatus (Odonata: Gomphidae). Archiv Fur Hydrobiologie: 144 (2) 229-244.