Community Ecology of Dragonflies

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Biography

Fred Singer received an A.B in Psychology from the University of Michigan in 1975, and a Ph.D. in Ecology from the University of Minnesota in 1987. He is now a Professor of Biology at Radford University, where he has taught about 15 different courses - most of them in the realm of general biology, zoology, ecology, behavior and evolution. He does research on behavioral ecology and how to teach.

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Introduction

On a typical body of water, males of several species of dragonflies may be found defending territories while searching for females. Different species are usually attracted to different habitats, and use contrasting approaches to find a mate. For example males of some species perch on vegetation, with occasional flights to inspect approaching dragonflies. In other species, males may spend most of their time in flight patrolling along a regular route for intruding males or potential mates. Differences in flight behavior and habitat preference may result from either of two factors: (1) an evolutionary history of interspecific competition, (2) morphological or physiological differences among the species. Both factors are strongly influenced by natural selection.

Many dragonfly communities will have about five common species, enough for there to be significant differences among species in habitat use and behavior, but not too much to frustrate students with identification challenges. The actual variables that students measure in the field will depend on the particular field conditions. For example, if the body of water is an open pond with emergent vegetation rimming the shore, it might be logical to include distance from shore, and vegetation density as important ecological factors that could differ among species. In my class, we did interspecific comparisons of how high the dragonflies flew, time in flight versus perching and territory size. These three variables were relatively easy to measure, and were likely to be important factors in the relatively ecologically homogeneous Radford University Wetland.

Student Outline

Conceptual objectives for an introductory class

1. A biological community is composed of numerous interacting species.
2. We can study and describe the differences in behavior and habitat preferences among different species within a community.
3. We can study and describe the interactions among different species within a community.
4. Numerous factors interact to define a species' niche within a community

Skill objectives for an introductory class

1. Identification of different species of dragonflies
2. Measurement of behavior and habitat preferences
3. For each variable, students will calculate the means and a measure of variation for each species.
4. For each variable, students will draw a conclusion about whether there are significant differences among species.

Additional conceptual objectives for an advanced class

1. Physiological factors (such as degree of endothermy) may limit the distribution of dragonflies in space or time.
2. Morphological factors (such as body size or wing-loading) may influence habitat preferences and behavior of different species.
3. There may be significant variation in behavior among individuals of different species.

Additional skill objectives for an advanced class

1. Comparison of means using ANOVA
2. Relationship between morphological differences and behavior using regression analysis
3. Development and implementation of individual research project

Background

Male dragonflies over a body of water find themselves in a fairly common predicament for organisms in a biological community. They must find mates of the correct species, mate with them, and make sure that no other males mate with their females before egg laying. This last point is particularly important, because most odonates (dragonflies and damselflies) have unique penises that function as shovels that can scoop out previously introduced sperm (Wagge 1979). Further complicating the task is that there is very little food for dragonflies over water, so that feeding and prospecting for mates are mutually exclusive activities. Lastly, while searching for mates over water, dragonflies must avoid getting eaten by predators.

Almost all of the dragonflies in this habitat are males. One hypothesis for this male-biased sex ratio is that males benefit tremendously from multiple matings, as each female they mate with, and that successfully lays eggs, will probably fertilize the eggs with the last male's sperm. On the other hand, females don't benefit very much from multiple mating, as one male provides them with sufficient sperm to fertilize all of the eggs. In fact mating can be a dangerous business for females, as the general frenzy caused by the conspicuous egg-laying may attract predators from the air and the water.

Field Activity Outline

Getting to know the dragonflies.

Each person should have a field notebook and follow three or four dragonflies. Write down everything that they do. Try to follow different species, so that you can get a feel for differences among species, and so that you learn to distinguish one species from another. Use the handout to help you with species identification (Appendix A). Please turn in your field notes after class.

Measurement of territory size and flight height.

A. Territory size. Many male dragonflies will be patrolling up and down a patch of wetland, eagerly awaiting the arrival of females. With practice and perseverance, you should be able to measure the extent and location of their territory. Here is the procedure:

1. Find a dragonfly and ID its species. Make sure everybody in your group agrees with its species ID, or find the instructor if you'd like help with the ID.
2. Set up your group members along the bank, so that you can continuously watch your dragonfly.
3. Observe for at least two minutes. You will no doubt lose sight of some of your subjects, in which case you should start again with a new observation.
4. Put down distinct forestry flags at the furthest extent of your dragonfly's flight path.
5. Measure the distance between the two flags.
6. Fill in your data on your data table (Appendix B)
7. Repeat at least four times with 4 different dragonflies.

B. Flight height. Dragonflies may fly at different heights above the water. Differences in flight height could partition space to reduce potentially costly collisions. This also could be a random process. In any case, let's see if they do this.

1. Find a dragonfly and ID its species. Make sure everybody in your group agrees with its species ID, or find the instructor if you'd like help with the ID.
2. Set up your group members along the bank, so that you can continuously watch your dragonfly.
3. Set up several marker flags along your transect so that you can record the height of each dragonfly as it flies by. Your instructor will show you how to do this.
4. Each time your dragonfly flies by a marker flag, record its height above the water.
5. Record at least five, and preferably ten heights for each dragonfly - this should be done at more than one marker flag.
6. If your whole group is measuring one dragonfly, get together after you've finished that dragonfly and combine your flight heights onto one data form (Appendix B).
7. Repeat at least four times with 4 different dragonflies.

Energy Budget.

One thing you will notice is that some species spend more time flying, while others spend more time perching. Your challenge is to follow an individual dragonfly for at least five minutes and keep track of how long it spends flying vs. perching. You will need two stopwatches and some coordination among your group. You can work out the details. See if you can do this for four dragonflies.

Capture-mark and release of marked dragonflies.

For the last half-hour of the lab we will attempt to capture and mark dragonflies. Your instructor will demonstrate how to do this. We will come back next week and see how many return to us.

Analysis of data (for an introductory level class)

I am warning you that you have been given raw data files. You will need to create new data files that are tailored to the assignment.

Your assignment is to answer the following three questions:

1. Do larger species of dragonflies tend to have larger territories?

To answer this you will need to figure out how big each species is. Please use the books in the lab, or else online sources to determine the species-typical size. Cite your references at the end of your assignment.

In your answer, make sure to include the following

a) a copy of your data table
b) identification of your dependent and independent variables
c) identification of your variables as categorical or continuous
d) a statement of your hypothesis
e) a graph (scattergram) showing your results
f) your conclusions

Essential hint: Each species should be one data point. This means we will be combining data to calculate a mean territory size for each species. For example, if you have 8 measures of territory size for a particular species, you'll need to calculate the mean of these 8 values to determine a point on your scattergram.

2. Do some species spend more time perching and other species spend more time flying?

In your answer, make sure to include the following:
a) a copy of your data table
b) identification of your dependent and independent variables
c) identification of your variables as nominal or continuous
d) a statement of your hypothesis
e) a graph showing your results
f) your conclusions

Essential hint: you'll need to convert your values to proportion of time spent flying (or perching). You should only include species for which you have two or more values in your data file so that your data are not skewed by one unrepresentative individual.

3. Do some species fly higher than other species?

In your answer, make sure to include the following:
a) a copy of your data table
b) identification of your dependent and independent variables
c) identification of your variables as nominal or continuous
d) a statement of your hypothesis
e) a graph showing your results
f) your conclusions

Essential hint: For each individual dragonfly, you'll need calculate a mean for your 5-11 measures of flight height, and then use those averages to calculate the averages for each species.

Analysis of data (for an advanced level class)

I am warning you that you have been given raw data files. You will need to create new data files that are tailored to the assignment. Your assignment is to answer the following three questions:
1. Do larger species of dragonflies tend to have larger territories?

To answer this you will need to figure out how big each species is. Please use the books in the lab, or else online sources to determine the species-typical size. Cite your references at the end of your assignment.

In your answer, make sure to include the following
a) a copy of your data table
b) identification of your dependent and independent variables
c) identification of your variables as nominal or continuous
d) a statement of your hypothesis
e) the value of your test statistic
f) the p-value
g) your conclusions

Essential hint: Each species should be one data point. This means we will be combining data to calculate a mean territory size for each species. For example, if you have 8 measures of territory size for a particular species, you'll need to calculate the mean of these 8 values to input into your data table. You can do this with a calculator, or a statistical software package.

2. Do some species spend more time perching and other species spend more time flying?

In your answer, make sure to include the following:
a) a copy of your data table

b) identification of your dependent and independent variables
c) identification of your variables as nominal or continuous
d) a statement of your hypothesis
e) the value of your test statistic
f) the p-value
g) your conclusions

Essential hint: you'll need to convert your values to proportion of time spent flying (or perching). You'll do an ANOVA on these data. Also report the Tukey results, so you can determine which species spent a significantly greater proportion of their time flying than do other species. You should only include species for which you have two or more values in your data file (there is no variance to analyze in a sample of one)

3. Do some species fly higher than other species?

In your answer, make sure to include the following:
a) a copy of your data table
b) identification of your dependent and independent variables
c) identification of your variables as nominal or continuous
d) a statement of your hypothesis
e) the value of your test statistic
f) the p-value
g) your conclusions

Essential hint: For each individual dragonfly, you'll need calculate a mean for your 5-11 measures of flight height, and then enter those averages into your data table.

Materials

The following materials are suitable for one 24-student section:
12 butterfly nets
24 3/8 inch wooden dowels (marked at regular intervals with tape, so students can estimate flight height of passing dragonflies).
100 forestry flags
12 stopwatches (or students may finally put their cell phones to good use)
6 30-m measuring tapes (anywhere from 25-50 m is fine)
Spreadsheet program &/or data analysis software (I use jmp)
6 rolls of masking tape

Notes for the instructors

Behavioral observations

The dragonflies will only be active if the sun is out (at least in all places that I've lived), usually between about 9AM and 5 PM. Some species are more active earlier in the day, while others stay around almost until sunset. Generally, there will only be about five species at a particular time of year, so students can learn to identify these in a half hour. Even if you don't know one or two

species, you can look them up in Sid Dunkle's spectacular and widely-available field guide (Dunkle 2000).

Some of the most interesting observations are associated with pre-copulatory, mating and postcopulatory behavior. Before mating, a males grabs the female by her head with claspers located near the tip of his abdomen and holds her in tandem. Depending on the species this may last for a few seconds or for a very long time (I don't know the record). The pair, if uninterrupted, will eventually get into the wheel position, with the male's penis (located ventrally on the 2nd and 3rd abdominal segment) engaging the female's vulva (located ventrally on the 8th abdominal segment). All this time, the male is still holding the female by her head with his claspers. It is as contortionist-looking as it sounds. Following mating, the pair will partially disengage (remain in tandem) or completely disengage, while the female oviposits. It is then that things get very interesting, as unmated males will attempt to takeover the female, while her initial male attempts to guard her. As you might imagine, different species have different methods of ovipositing and guarding. Needham and Westfall (1959) is a good classic reference on North American dragonflies, and what goes where.

Choice of variables

The three variables described in this paper are easy to measure and will generally differ among species. They also are likely to vary at the Radford University Wetland, while some other biologically-relevant variables will not vary very much. Measuring these variables is relatively straightforward, but there will always be some error to deal with. When measuring territory size, you may face a conundrum of whether to use a linear or area measurement. At the Radford University Wetland, linear measurements were suitable, because the drainage system is very linear. In most cases, you will be able to justify a linear measurement, but your best students may (rightfully) complain. For measuring flight height, I put dowels into the ground and attached forestry flags to them forming an ungainly structure about two meters tall. I marked every 20 cm with tape, and had thicker tape at the 1-meter mark. You can engage students in designing them. For the energy budget observations you will need to coerce the students into doing a lot of yelling. It is lots of fun to hear them shouting "incoming *Libellula pulchella*."

The variables you choose to measure should be suitable to your habitat. For example, many studies have shown that different species tend to be found at different distances from the shoreline, but the Radford University Wetland is so narrow, that distance from the shoreline has very little meaning. Other variables may be suitable for different bodies of water. Perhaps the most relevant are vegetation height (for perching species) and vegetation density. Students can certainly be encouraged to choose their own variables, or to look for correlations among the variables, if you want to introduce concerns about spurious correlations.

One advantage of using the Radford University Wetland as the field site is that it is mapped, so we can (hopefully) make year-to-year comparisons of community composition and also phenology. With changing climate, this promises to be an interesting route to pursue. I encourage you to set up a permanent grid system, so that you can see and document changes from year-to-year and season-to-season.

Data analysis

The data can be analyzed at different levels of detail, depending on your student body and course level. Kugler et al (2003) have a thorough discussion of teaching hypothesis testing and data

analysis in an introductory course, including approaches to comparisons of means and simple correlation analysis. I developed this lab for an upper-level ecology course, and used it as my introduction (to them) of ANOVA and simple linear regression.

I used Excel to summarize the data, but required students to convert the files to a format suitable for our data analysis package (jmp 5.1.2). By giving students unpolished data files, they are required to think carefully about the hypothesis they are testing. To reinforce this process, I presented students with questions in the analysis handout requiring them to identify dependent and independent variables as nominal or continuous.

Bad weather options

I had the misfortune of presenting this workshop during unseasonably cold and cloudy days in Toronto. My semi-satisfactory solution (alliteratively asserted), was to have the students dress up as dragonflies (dragonpeople), and behave as such in the water. I met with the dragonpeople beforehand, and we decided to create a counterintuitive inverse correlation between body size and territory size. Thus tall dragonpeople "flew" over small areas, while less tall dragonpeople "flew" over larger areas. There were interesting agonistic interactions when dragonpeople's territories overlapped, which resulted in the appropriate amount of chaos characteristic of dragonfly communities. Most important, there was a highly significant inverse correlation between dragonpeople size and territory size.

A second option is to build some flexibility into your schedule, so that you have an indoor lab backup, in case the sun refuses to shine on lab day.

Acknowledgements

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Literature Cited

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Needham, James G., Westfall, Minter J. jr. 1959. *A Manual of the Dragonflies of North America.* University of California Press, Berkeley.

Waage, John K. 1979. Dual function of the damselfly penis: Sperm removal and transfer. Science 203: 916-918.

www.jmp.com

Appendix A

I created a handout of full-color full-body dragonflies of southeastern Canada that are active in early June. I put these in plastic covers, so they would survive multiple lab sessions. I used Dunkle's book (2000) as a reference for geographic range and time of year, and then used the following two websites as sources of the pictures:

http://www.netcore.ca/~prairie/odonata.html

http://www.npwrc.usgs.gov/resource/distr/insects/dfly/index.htm

Appendix B

Names of Researchers _____

Territory size summary

Species	Duration of observation (sec)	Territory size (nearest 10 cm)

Flight height Summary (at least 5 measures per individual)

Species	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11

Note: measure flight height to the nearest 10 cm. H1 is the first height measurement, H2 is the second height measurement for the same dragonfly.

Energy budget. All times should be in total seconds (in other words 2 minutes and 20 seconds must be recorded as 140 seconds)

Species	Time flying	Time perching	Comments
