Trophic cascade interactions in Northern Wisconsin sphagnum bogs

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Abstract

Predation has important indirect effects that often transfer across ecosystems. For instance, in ponds, fish have been shown to indirectly facilitate plant reproduction through predation of dragonfly larvae. Adult dragonflies prey on pollinating insects such as bees, butterflies, and flies, thereby negatively affecting the reproduction of nearby plants. In this study, similar trophic cascade interactions between fish, dragonflies, pollinators, and plants were examined across sphagnum bog ecosystems in Northern Wisconsin. The objectives of this study were to (1) determine whether high dragonfly abundance impedes flowering plant reproduction and richness around bogs through predation of pollinators, and (2) determine whether presence of fish has an impact on dragonfly populations. Study sites included 4 bogs that did not support fish and 4 bogs that contained fish, and the vegetation was sampled at each site in order to obtain a total flowering plant density. Pollinator visits to flowers were observed and dragonfly abundance was quantified over 3 separate sampling events at each site. Results showed that dragonfly abundance did not have any impact on the density of flowering plants, however, there was a strong trend suggesting that greater numbers of dragonflies correlated to decreased plant richness. The impact of fish on populations of dragonflies was shown to be statistically significant in that the presence of fish significantly decreased the abundance of dragonflies. Number of pollinator visits was not dependent on dragonfly abundance. These results suggest that, in stressed ecosystems such as bogs, abiotic factors such as nutrient availability play much greater roles than biotic trophic interactions in determining plant distributions, thereby limiting the cascading effects of predation across ecosystems.

Introduction

Population dynamics and food-web interactions are dependent on the specific composition of species in an ecosystem, in addition, predation can limit the ability of certain species to survive as predation causes both direct and indirect effects across ecosystems. Often the presence or absence of a predator can have dramatic effects on species abundance and richness due to cascading trophic interactions. In freshwater ecosystems, fish prey on dragonfly larvae and adult dragonflies prey on many species of insects, including pollinator insects such as bees, flies, and butterflies. These interactions lead to fish indirectly facilitating plant reproduction. Decreased dragonfly and damselfly abundance corresponds to a greater number of pollinators and therefore increased plant reproduction (Knight et al 2005). It has also been shown that insects that prey on pollinators decrease seed production in plants by reducing the frequency and duration of floral visits by pollinating insects (Suttle 2003). Odonates impact vegetation in this manner by reducing pollinator visits to flowers, as pollinators behaviorally avoid foraging near adult dragonflies (Knight et all 2005).

Bog plants often reproduce by producing flowers that are fertilized by pollen to make seeds, however, most also reproduce by spreading rhizomes. Nonetheless, sexual reproduction, which requires pollinators, is the preferred method of reproduction. Many of the plants surveyed have evolved strategies to attract pollinators: the anthers of swamp laurel's flowers (*Kalima polifolia)* are caught in shallow pockets in the corolla, creating tension such that if an insect touches the stamens while drinking nectar the stamen will spring out and deposit a load of pollen on the insect (Cronk and Fennessy 2001). Labrador tea, *Ledum groenlandicum,* also emits strong smells to attract bees and other pollinating insects (Chadde 1998). In addition, the pollen of the cranberry plant, *Vaccinium oxycoccus,* is heavy and is not wind blown, therefore making insects necessary for adequate pollination (Ortwine-Boes and Silbernagel 2003).

The purpose of this study was to examine the indirect effect of fish predation on plant communities. The main objective, however, was to study the specific trophic interaction between dragonflies and plants via pollinators. The hypothesis for this study is that decreased numbers of dragonflies and damselflies will correlate to greater abundance of flowering bog plants. Subsequent predictions include the following: (1) the presence of fish will negatively impact dragonfly abundance, and (2) larger numbers of dragonflies will correspond to fewer pollinators. Specifically, I will study both larger bogs with fish and smaller bogs without fish. Odonates prefer large, stable, vegetated pools of water (Larson and House 1990), and UNDERC's bogs provide these conditions.

Methods

Eight bogs were selected as study sites. Four of the bogs had fish present: Bolger Bog, Hummingbird Bog, Cranberry Bog and Tuesday Bog. Four bogs did not support fish communities: Beaver Bog, North Gate Bog, Tender Bog and Forest Service Bog (UNDERC, unpublished).

Pollinator Observations

Pollinators were observed at each study site. Types of pollinators and the frequency of their visits will were noted. Shrubs with a bunch of four flowers of similar size and stage of flowering were observed at each bog over a 20 minute period. Pollinator observations were repeated three times per bog, on the same day and time that the dragonflies at the site are counted.

Vegetation Sampling

Vegetation was systematically sampled using evenly spaced one-square-meter plots along 5 transect lines. Each transect line was 10 meters long and began at the shoreline of the bog, running outward and perpendicular to the open water. Transect lines were evenly space around the shoreline according to the circumference of the open water of the bog. Plots along the transect were spaced 2 meters apart, with 4 plots altogether per transect line. In order to get a flowering plant density, or abundance measure by actual count per unit area, all the flowering plant branches within each 1 m^2 plot were counted.

Odonata Sampling

Odonata abundances were quantified by using the same transect lines used for vegetation sampling. Adult odonates that entered an area approximately 5 meters to the front and 1 meter to either side of my positioning on the line were counted as I walked along each of the 5 transect lines at a consistent pace of 10 meters per minute. A stopwatch and counter were used during odonate sampling. Each sampling event covered all sites and measured odonata abundance on warm (between 26 and 29 degrees C), low-wind, sunny days between the hours of 10:00 am and 3:00 pm. The census of all the study sites was completed within 2 to 3 consecutive days, depending on the weather. Odonata sampling was repeated a total of 3 times over a 5 week period over all of the sites. Sites within the survey were visited in differing order.

Results

A regression showed that plant density showed no statistically significant difference in relation to abundance of dragonflies (R^2=0.155, p-value=0.334). (figure 1). The relationship between pollinator abundance and dragonfly abundance was not statistically significant (R^2=0.1766, p-value=0.2998). An ANOVA also showed that dragonfly abundance did vary statistically significantly over fish and fishless bogs (F-ratio=1.087, df=1, p-value=0.0033) (figure 4), while plant density did not **(**F-ratio=2.077, df=1, p-value=0.1996**)** (figure 2). Regressions indicated that the only abiotic factor that was statistically significant when compared to plant abundance or richness was conductivity, which was shown to increase with increasing abundance of plants (R^2=0.5284, p-value=0.0412) (figure 5). Plant abundance was not statistically significantly different when compared to abundance of dragonflies, however, there was a strong trend towards richness being negatively correlated to dragonfly abundance (R^2=0.4549, p-value=0.0665) (figure 3).

Discussion

The results of this observational study suggest that fish predation does not indirectly facilitate plant reproduction in bogs. Dragonfly predation was shown to hold little importance in the trophic cascade linking fish, dragonflies, pollinators, and flowering plants; thus the overall hypothesis of this study must be rejected, as greater dragonfly abundance was not related to lower abundances of flowering plants. The data does suggest, however, that fish predation on dragonfly larvae has a large impact on dragonfly populations, so the prediction that there would be lower numbers of dragonflies in bogs with fish was supported by the data. While fish predation had a large impact on dragonfly populations, the results of this study demonstrate that the effects of aquatic predation do not always reverberate across ecosystems.

The number of pollinators was not statistically significant when compared to dragonfly numbers or to the presence of fish in the bogs, which implies that dragonfly predation on insects has little or no effect on numbers of pollinators. This could be due to large numbers of mosquitoes, gnats, and other non-pollinating insects that provide ample food for dragonflies, thereby lessening the impact of dragonfly predation on populations of pollinators such as butterflies and bees. The abundance of insects also could explain why the presence of fish did not have an impact on the number of pollinators. The reason that, despite the abundance of insects serving as food for the fish, the fish still reduced dragonfly populations, could be because dragonfly larvae in the water are easier for fish to access and prey upon than terrestrial flying insects that must fall into the water.

The trend towards lower richness of flowering plants at bogs with higher numbers of dragonflies could be due to the fact that leatherleaf, a pioneer plant species that helps to develop the sphagnum mat, was present in high abundance on the lesser-developed sphagnum mats of fishless bogs (where there were more dragonflies because of the lack of fish). The number of pollinators did not change with dragonfly numbers or with changing richness or abundance of flowering plants, suggesting that pollinators are most likely not a factor, however a more detailed study should be done on pollinator abundance and visitation rates and the relationship to plant richness.

Although presence of fish or decreased abundance of dragonflies did not have any relationship to plant abundance as initially hypothesized, the results showed that conductivity had a positive relationship to plant abundance. As conductivity increased, so did the density of flowering plants at each site. This result, in addition to the result showing that pollinator numbers had no effect on plant distributions, suggest that abiotic factors have more influence on vegetation structure than trophic cascade interactions. Low conductivity can sometimes be a measure of nutrient deficiencies, explaining why there was a lower abundance of plants at lower conductivities (Newbould and Gorham 1956). Only the shoreline water conductivity was measured, however, and so in order to make a more accurate conclusion between nutrient availability and plant abundance the substrate conductivity should be measured, and specific nutrients tested for.

This study was based off of the Knight et al. study that was preformed using ponds, so the type of wetland studied could explain the conflicting results between the two studies. Pollinator abundance could have a greater impact on vegetation distribution around ponds than around bogs due to the differing abiotic factors that influence vegetation patterns at bogs. Open Bogs in northern regions and are cold, acidic, weakly minerotrophic wetlands with no through-flow of nutrient rich water in the substrate. Thus bogs are stressed ecosystems where few plants are able to survive. The strategies bog plants use in order to survive include, above all, a frugal use of nutrients (Haslam 2003). Plant abundance at bogs is more likely than ponds to be dependent on abiotic factors such as water chemistry and nutrient availability, as high pH and low nutrients can limit the type of plants and number of plants living in a certain area around the bog.

Another example of abiotic factors possibly having more influence than biotic interactions is stage of succession of the bog, which is related to the thickness of the sphagnum mat. The thickness of the mat can be an important factor determining whether or not certain plants can colonize an area. Taller plants such as larger trees and shrubs are able to colonize thicker-mat areas, creating greater shade cover and therefore limiting the amount of flowering plants in that area. For example, leatherleaf is shade intolerant and begins to thin as tall shrubs or bog forest species such as tamarack (*Larix laricina*) and black spruce (*Picea mariana*) establish themselves on the mat (Crumm 1992). Future studies, then, are needed to understand how much of an impact pollinator activity has on the reproduction and abundance of bog plants in comparison to other important factors determining vegetation distribution such as water chemistry, nutrient availability, herbivore predation, water saturation, inter- and intraspecies competition, stage of succession, and light intensity.

Finally, frequency and impact of pollination methods on vegetation abundance and richness, as well as type of wetland, must be taken into account. Many plants that colonize bogs are able to reproduce by rhizome when unable to reproduce sexually. Future studies dealing with genetics and pollen distributions are needed to determine how often flowering plants in fish and fishless wetlands are reproducing sexually compared to asexually.

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Literature Cited

Briers, R. A., and J. Biggs. Marine and Freshwater Ecosystems. *Journal of Aquatic Conservation* vol. 13, 4:323-330.

Buell, M. F., H. F. Buell and W. A. Reiners. 1968. Radial mat growth on Cedar Creek Bog, Minnesota. *Ecology* 49: 1198-1199.

Buskirk, J. V. 1988. Interactive Effects of Dragonfly Predation in Experimental Pond Communities, *Ecology* 20:707-715.

Chadde, S. W. 1998. A Great Lakes Wetland Flora. Pocketflora Press, Calumet, Minnesota.

Cronk, J.K and Fennessy, M. S. 2001. Wetland Plants: Biology and Ecology. CRC Press.

Crum, Howard. 1992. A Focus on Peatlands and Peat Mosses. The University of Michigan Press, Ann Arbor, Michigan.

Haslam, S. M. 2003. Understanding Wetlands: Fen, Bog and Marsh. Taylor and Francis Inc, New York, NY.

Knight, T. M., M. W. McCoy, J.M. Chase, K.A. McCoy and R. D. Holt. 2005. Trophic Cascades Across Ecosystems. *Nature* 437:880-883.

Larson, D. J. and N. L. House. 1990. Insect communities of Newfoundland bog pools with emphasis on the Odonata. *Canadian Entomologist* 122:469-501.

Ortwine-Boes, C. and J. Silbernagel. 2003. Bumblebee conservation in and around cranberry Marshes. Department of Landscape Architecture, University of Wisconsin-Madison.

Newbould, P.J. and E. Gorham. 1956. Acidity and specific conductivity measurements in some plant communities of the new forest valley bogs. The Journal of Ecology, 44:118-128

Reader, R.J. 1977. Bog ericad flowers: self-compatibility and relative attractiveness to bees. *Canadian J. Bot*. 55:2279-2287.

Sahlen, G. and K. Ekestubbe. 2004. Identification of dragonflies as indicators of general species richness in boreal forest lakes. *Journal of Biodiversity and Conservation* 10:673-690.

Suttle, K. B. 2003. Pollinators as mediators of top-down effects on plants. *Ecology* 6:688-694.

U.N.D.E.R.C. website. Environmental Research Center-East. 2004. University of Notre Dame. Accessed 20 May 2008. <http://www.nd.edu/~underc/east/about/visitors_guide.shtml.>

University of Notre Dame. 1993. Guide to U.N.D.E.R.C.: University of Notre Dame Environmental Research Center. Unpublished.

Tables

Table 1: *Flowering plant stem density per square meter by site.* Shaded columns to the left of the table represent bogs that contain fish.

	BG	CR	HM	TU	BV	FS	NG	TD
Leatherleaf *(Chamaedaphine calyculata)*	42.4	28.75	11.0	27.95	76.75	26.0	49.2	77.65
Pitcher Plant *(Sarracenia purpurea)*	1.5	3.3	0	4.65	2.3	6.37	0	2.95
Bog Laurel *(Kalmia polifolia)*	10.4	17.2	0.4	17.6	12.3	8.3	13.7	16.05
Rosemary *(Andromeda glaucophylla)*	0.45	2.5	0	0	0	2.45	0.5	0
Cranberry *(Vaccinium oxycoccus)*	27.75	11.5	8.15	8.5	25.1	0	7.9	21.9
Labrador Tea *(Ledum groenlandicum)*	0	31.95	13.55	7.5	27.35	2.85	35.6	7.9
Sundew *(Drosera spp.)*	0.1	0.9	0.3	0	0	3.45	0	0
Creeping Snowberry *(Gaultheria hispidula)*	0.15	1.5	4.0	0	0.25	0	17.4	0
Bog Iris *(Iris spp.)*	0.05	4.05	0.15	1.0	0.05	0.05	0	0
Swamp Cinquefoil *(Potentilla palustris)*	1.35	0	0	0	0	0	0	0
Buckbean *(Menyanthes trifoliate)*	0.55	0	0	0	0	0	0	0
Sweet Gale *(Myrica gale)*	0	1.1	2.30	0	0.15	0	1.25	0
Raspberry *(Rubus spp.)*	0	0	0.75	0	0	0	0	0
Highbush Blueberry *(Vaccinium corymbosum)*	0	0	1.15	0	0	0	0	0
Bunchberry Dogwood *(Cornus canadensis)*	0	0	1.0	0	0	0	0	0
Bearberry *(Arctostaphylios uva-ursi)*	0	0	0	0	0	0	0.95	0
Canada Mayflower *(Maianthemum canadensis)*	0	0	3.1	0	0	0	0	0
Bog Willow *(Salix pedicellaris)*	0.65	0	0	0	0	0	0	0
Ladyslipper Orchid *(Cypripedium spp.)*	1.6	0	0	0	1.0	0	0	0
Starflower *(Trienalis borealis)*	0	0	5.3	0	0	0	0	0

BG = Bolger Bog
CR = Cranberry Bog
NG = North Gate Bog
BV = Beaver Bog
HM = Hummingbird Bog
TU = Tuesday Bog
FS = Forest Service Bog
TD = Tender Bog

Table 2: *Total plant richness and density, as well as dragonfly abundance, by site.*

Study Site	*Fish*	*Flowering Plant Richness (total species)*	*Total Density of Flowering Plants (Plants/m^2)*	*Dragonfly Abundance (Avg. # dragonflies/min)*
Bolger	Yes	12	87.00	3.67
Cranberry	Yes	10	102.8	7.60
Hummingbird	Yes	13	51.15	1.93
Tuesday	Yes	6	67.2	5.13
Beaver	No	9	145.3	6.13
Forest Service	No	7	49.15	9.07
North Gate	No	8	126.5	8.87
Tender	No	5	126.5	8.27

Figures

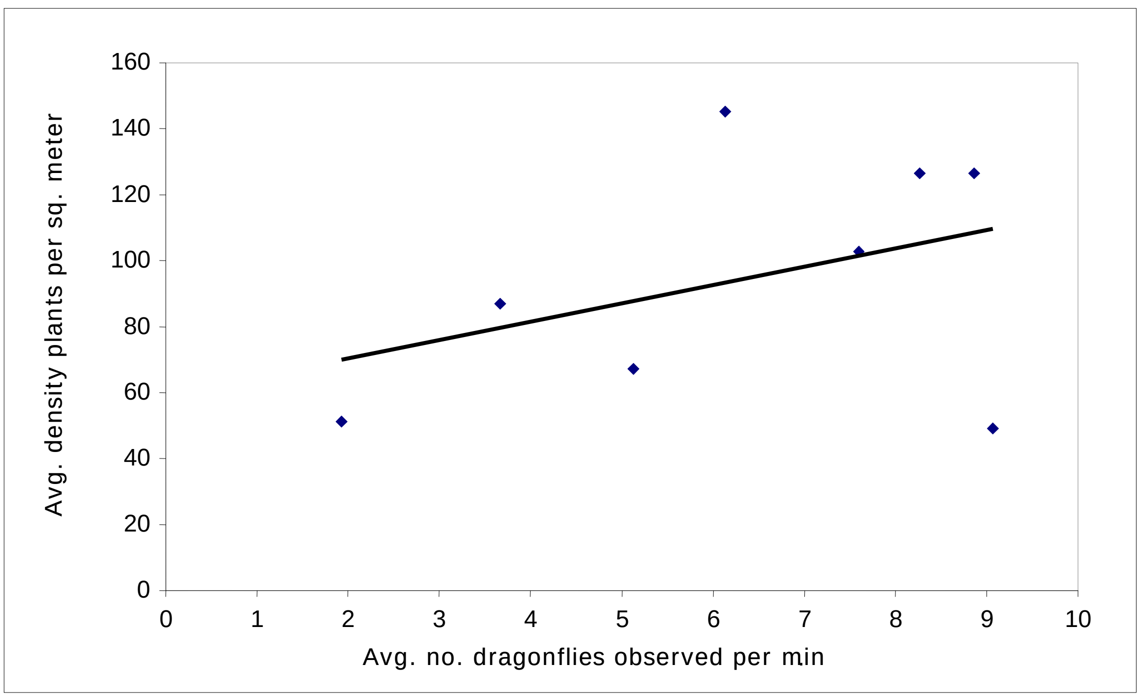

Figure 1: *Average flowering plant density compared to dragonfly abundance* (Regression: p-value=0.3344, R^r=0.1551). Results showed no statistically significant relationship between dragonfly abundance and plant density ($p \leq 0.05$).

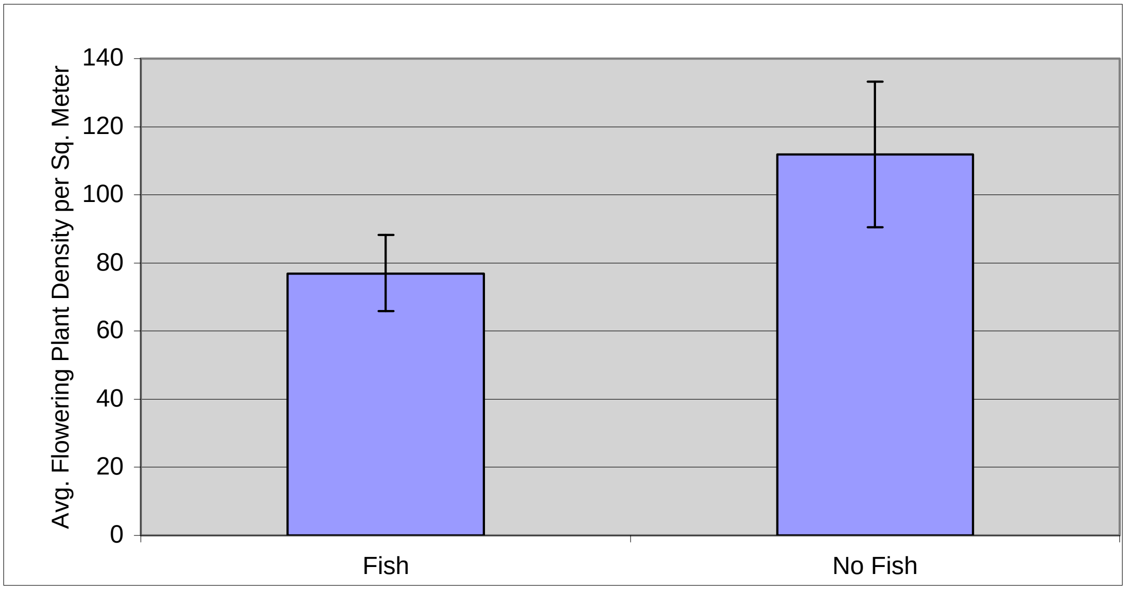

Figure 2: *Average flowering plant density across fish and fishless bogs* (ANOVA: F-ratio=2.077, df=1, p-value=0.1996). Results showed no statistically significant relationship between presence of fish and plant density ($p \leq 0.05$). Error bars represent standard error.

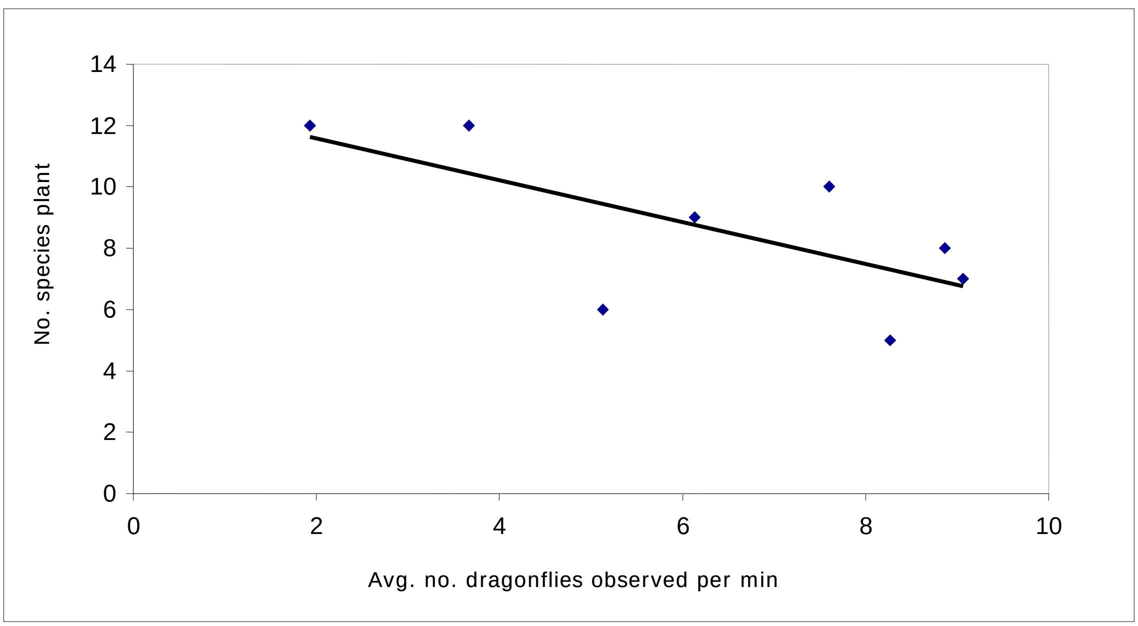

Figure 3: *Flowering plant richness as a function of dragonfly abundance.* Results showed a strong trend towards plant richness decreasing with increasing numbers of dragonflies (F-ratio=5.008, df=1, p-value=0.0665).

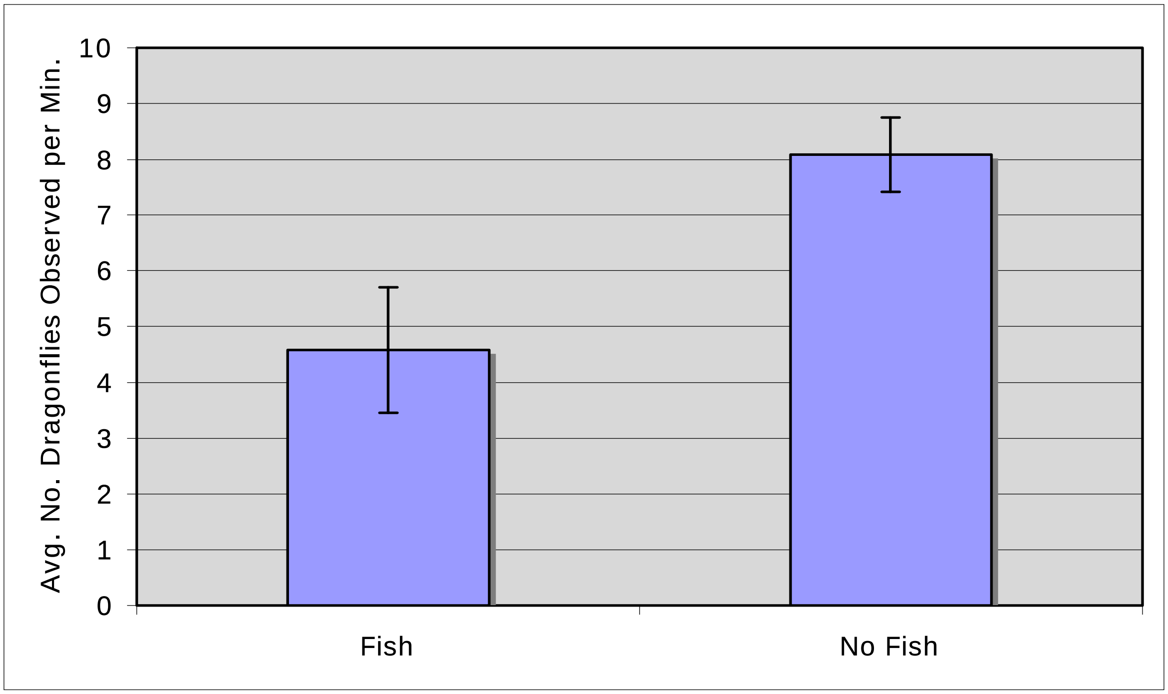

Figure 4: *Dragonfly density observed across fish and fishless study sites* (ANOVA: F-ratio=1.087, df=1, p-value=0.00328). Error bars represent standard error.

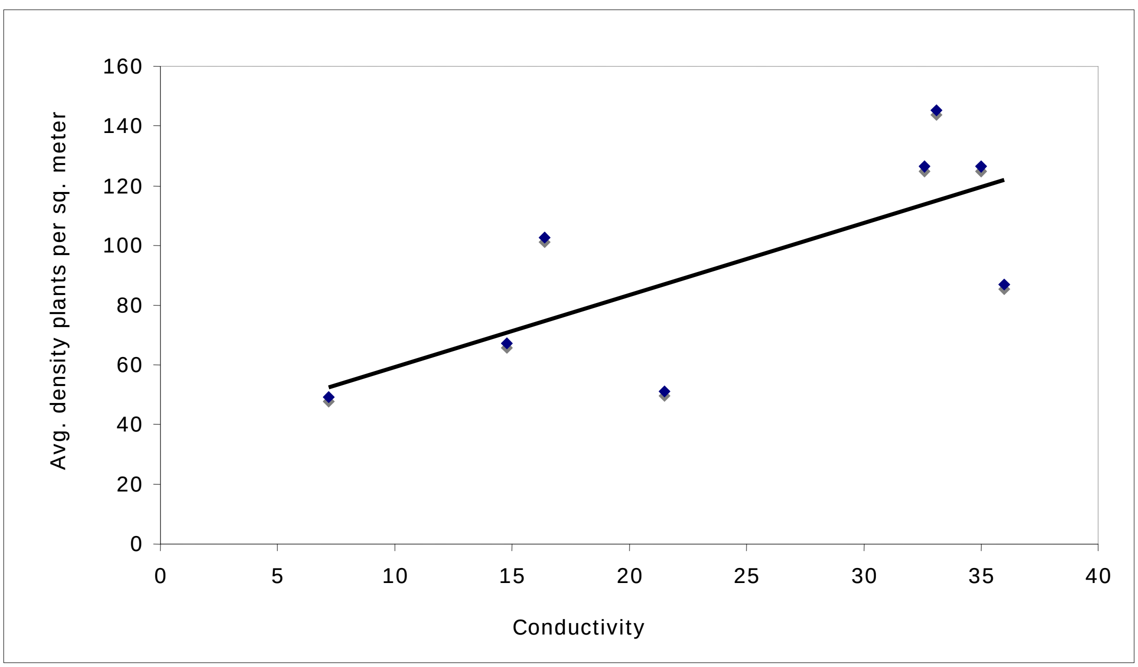

Figure 5: *Density flowering plants as a function of conductivity*. Overall, the average density of plants per square meter increased as conductivity of the bog increased (Regression: P-value=0.0411, R^2=0.5284).

Appendix

Appendix 1: *Physical properties measured at study sites.* Only conductivity was shown to be a statistically significant in relation to plant abundance or richness.

Study Site	*Avg. distance from open water to forest edge (m)*	*pH*	*Conductivity*	*Dissolved Oxygen*
Bolger	16	6.9	36.0	6.91
Cranberry	45	4.8	16.4	6.01
Hummingbird	25	5.1	21.5	7.20
Tuesday	40	5.8	14.8	7.40
Beaver	11	3.8	33.1	5.89
Forest Service	35	5.1	7.2	6.56
North Gate	15	4.5	32.6	6.08
Tender	7	4.5	35.0	8.47