

**Defense Mechanisms in Spotted Salamanders (*Ambystoma maculatum*) Induced by  
Perceived Predation Risk as a Response to Differing Cues**

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**Abstract**

Predation is among the most important factors to understand the ecology, behavior, and evolution of animal species. The detection of visual cues and kairomones (chemical) released by predators allows the prey to find a way to increase their chances of survival and fitness.

*Ambystoma maculatum* can be top predators in their adulthood but often suffer from high rates of predation as larvae and, therefore, rely on the use of these cues to avoid predation. However, the interaction between two or more cues and how the prey use it as a way to avoid predation is something poorly understood. In this experiment, we studied how the visual and chemical cues induced by dragonfly nymphs and diving beetles influence the anti-predator defenses of *A. maculatum*. We did not find a difference between the morphological responses of *A. maculatum* and the type of predation they faced. We found that larvae reduced activity in the presence of predators and that they had no preference when selecting a refuge. We also found that *A. maculatum* is more susceptible to perceiving chemical signals from predators. This is one of the first studies showing a decrease in the mass and length of *A. maculatum* during the larval stage when facing predators from its natural habitat. We discuss these results and provide a theoretical framework for future studies of predation perceived risk.

**Introduction**

Predator-prey dynamics can influence prey populations through consumptive effects, like hunting and killing, or through increasing the risk of consumption (Preisser and Bolnick 2008). Predation risk is a significant influence on changes in behavior, morphology, development, reproduction, and diet of the species that are a target as preys (Dwyer 2009). Still, these defensive strategies often have significant costs that reduce prey fecundity or survival (Preisser and Bolnick 2008). Those demands are often mediated by the time and resource allocation trade-

offs (Steiner and Pfeiffer 2007). Resource reallocation is often limited by competing traits, such as growth, maintenance, reproduction, and storage (Steiner and Pfeiffer 2007) and that is why many animals do not develop these defensive traits unless they are necessary. Therefore, the effectiveness and benefits of such traits will be dependent on the speed at which they can be expressed relative to the time when the risk began and the duration of it (Mitchell et al. 2017). Behavioral and morphological defenses are often plastic and only appear when the prey senses predation risk (Steiner and Pfeiffer 2007) but once they invest in the development of new characteristics or behaviors to survive, they can be permanent. Behavioral responses are usually associated with the reduction of activity and increased refuge use or hiding, and temporal and spatial avoidance of predators (Shaffery and Relyea 2015) while changes in morphology can include changes in growth or developing secondary structures to improve survival (Urban 2010; Dawidowicz and Loose 1992). Prey can also invest in the alteration of life-history traits like hatching plasticity (Dwyer 2009) and changes in time to metamorphosis (Shaffery and Relyea 2015). Prey utilize a variety of sensory inputs such as visual, chemical, tactile, and auditory cues to detect and avoid predators, and the type of cue can have strong effects on the type of response elicited by the prey (Lönnerstedt 2013).

In aquatic environments, visual chemical cues have been identified as a primary source of information for both vertebrates and invertebrates (Elvidge and Brown 2012). Visual cues are useful in predator recognition because they can provide information on the predator's location and whether it is actively hunting or not (Shelton 2016). However, this type of cue is limited by photoperiod and the effectiveness can easily be compromised (Elvidge and Brown 2012). For example, using visual cues in lentic areas such as wetlands and ephemeral ponds can be less effective because they have low light due to turbidity of the water or due to structural visual

disruptions such as vegetation (Shelton 2016; Gardner 2019). Instead, many aquatic amphibians rely on the kairomones to avoid predation because predators and prey often are in close proximity and the exposure to chemical cues tend to be more intense than visual (Murray et al. 2004). Chemical cues can provide information about temporal and spatial predation risk and therefore allow the prey to regulate the expressions of inducible defenses based on proximate risk (Mitchell et al. 2017). These cues are a cocktail of two types of chemical cues: the ones derived by predators (kairomones; odors and diet) and from conspecifics or prey guild member (near attacks) (Mitchell et al. 2017). They have a relatively long duration compared to the other types of cues, and also provide information about the past presence of predators (Shelton 2016). The effectiveness of these cues relies on the fact that they can cross barriers that otherwise would limit the predation risk identification by the preys until it is too late (Shelton 2016). Separately these cues can induce different behavioral responses and many animals are relying on using multiple cues to accurately assess predation risk levels (Lönnerstedt 2013), however the interactions between two or more cues together is poorly understood.

Even though there are some clear benefits for behavioral responses to predation signals, it also involves a cost for the sustainability and survival of the species, especially since some of these changes are permanent. Spotted salamanders (*Ambystoma maculatum*) are used in perceived predation risk experiments because they can behave as intermediate or top predators as adults but suffer from high levels of predation in the larval stage from a variety of predators (Shaffery and Relyea 2015). *Ambystoma maculatum* typically breed in seasonally ephemeral pools and have high fidelity to these breeding ponds (Pfungsten et al. 2013). Once they hatch, larval survival is limited due to competition for food sources, aggression, cannibalism, and predation. Common predators consist of aquatic vertebrates like fish and turtles, or aquatic

insects such as diving beetles and dragonfly nymphs. Predation risk changes based on foraging strategies employed by predators, and larval *Ambystoma* are known to change their behavioral and morphological responses based on these different strategies (Rack 2016; Urban 2008). For example, *A. gracile* is active at day at night in lakes that lack predatory fish, but in the presence of trout they are strictly nocturnal (Petranka et al. 1987). Dragonfly nymphs use an ambush technique in which they wait for their prey to pass by so they can catch it (Berger and Hansen 2004; George 2013). Diving beetles, on the other hand, feed themselves by swimming through the water, cling to the prey and use their mandibles to inject a digestive enzyme (George 2013, Johansson and Nilsson 1992). Spotted salamander's larvae respond uniquely to chemical cues from different predator species and employ different adaptations to escape accordingly (Rack 2016; Urban 2010; Urban 2008). These responses can be genetically innate or learned, which typically arise from exposure to a predator (Albecker and Vance-Chalcraft 2015). However, innate responses are more common in the younger stages because these evolved reactions can help the prey to diagnose the level of threat present in the environment even without any previous experience with the predator (Albecker and Vance-Chalcraft 2015).

This study aims to determine how the visual and chemical cues issued by predators influence the defense mechanism of *A. maculatum*. Additionally, we tested if cue responses of *A. maculatum* differ according to the identity of two naturally-occurring predators. We hypothesized that the larvae respond differently to different cue-types. An increase in length and body mass is expected as a result of the defense mechanisms developed to avoid predation, and this would be more pronounced when larvae are exposed to chemical cues than visual cues. Being able to see predators will increase the chances of dying due to the energy investment, limitation of food sources, and the immediate danger they face. In order to avoid been detected

by predators, the larvae will reduce the activity and increase the use of refuge. Our objective was to evaluate how the predator-prey interactions affect the development of anti-predator traits and the importance that they have in the evolutionary and developmental level of this species.

## **Methods**

*Study Site* – The study was conducted in the University of Notre Dame Environmental Research Center (UNDERC) located between the state line of Wisconsin and Michigan's Upper Peninsula in Vilas County (Wisconsin) and Gogebic County (Michigan). The property comprises over 7500 acres which are divided between a land area of 6150 acres with 30 lakes and bogs and 1350 acres that include a combined area. It has a variety of aquatic and terrestrial habitats that include vernal ponds, marshes, sluggish headwater streams, coniferous forest, mix, and non-mix deciduous forests (Jones 2017).

*Animal collection and rearing* – We collected by hand from May 27, 2019-May 30, 2019 from twelve different ponds (Fig. 1a; Table S1). I used masses from ponds J, A2, N, Wood Duck, and V to ensure genetic diversity. The females show a preference for the same breeding pond, so they travel to it to lay their eggs there every year and only move to others when they have been altered or destroyed (Shoop 1968). We used two types of predators: diving beetles from the family Dytiscidae and dragonfly nymphs from the family Aeshnidae. Predators were collected through dip netting and minnow traps. The first round of predators was caught on May 30, 2019, at Morris Lake and on June 6, 2019 five minnow traps were set in two vernal pools, Wood Duck and Pool 9, for a total of 10 traps (Fig. 1b). Minnow traps were checked once a day until June 13, 2019. The egg masses were housed individually until they hatched, at which point they were housed communally by egg mass and hatch date. Predators were also housed individually until

we began the experiment. All animals not used in the experiments were returned to the pool they were collected from.

*Experimental design* - The experiment began on June 15, 2019 and was conducted under lab conditions at UNDERC-East. Salamander larvae from each of our five experimental broods were randomly assigned to one of four experimental treatments: non-visual/chemical (NVC), visual/non-chemical (VNC), visual/chemical (VC), and non-visual/non-chemical (NVNC). The treatments each correspond to predator cues available to the salamander larvae. This was repeated for our two predators, resulting in 8 treatments total. We placed 6 salamander larvae from a single brood in each tank (34.6 cm x 21 cm x 12.4 cm), with a total of 4 tank replicates per treatment, resulting in 192 salamander larvae in 32 tanks. Predators were added to 300 mL cups secured inside of the tank. This allowed the predator to be present in the system without coming into contact with the larvae. To limit visual cues, cups were spray-painted white, and to allow for chemical cues to enter the system, we put 24 holes in the cups to allow for water to pass. For shelter, 300 mL cups were cut in half and spray-painted brown. Weight and length were measured the day that the larvae were placed in the tank (Day 0), halfway through the experiment (Day 14, June 30, 2019), and at the end of the experiment (Day 28, July 13, 2019). We fed the animals and did water changes on alternating days three times per week. The larvae were fed *Daphnia* and the predators black field ants. Additionally, behavior tests were run for feeding response and shelter use. Animals were observed before and after feeding for shelter use for 60 seconds.

*Statistical analysis* - We ran a Shapiro-Wilk test for data normality for both mass and length for each day of measurement of both predators. Non-normal data was converted using a  $\log_{10}$  function. We also ran a one-way ANOVA for mass and length of each predator per day to see if

there was a variance between the time and development of the salamanders. To test the salamanders' response to predator cues, we ran a two-way ANOVA for mass and length of each predator for each measurement day using the interaction of visual cue presence and chemical cue presence. To test survival in each treatment, we ran another two-way ANOVA comparing survival at the end of the experiment with the same independent variables. For each ANOVA with significant results, we ran a Tukey's HSD to determine the pairs with significant differences. Finally, we tested behavior shifts possibly due to cue presence using a chi-square test. RStudio v. 3.6.1 was used to run all the statistical tests and Microsoft Excel was used to make all the graphs.

## Results

Hatching of the larvae began on June 1, 2019 and end in June 9, 2019 (Table S2). Three measurements for mass and length were made during twenty-eight days of running trials before the data was analyzed. The Shapiro-Wilk test showed normality in the data (Table 1). There was a significance difference between the mass and length on the chemical treatments for both diving beetles and dragonfly nymphs' trials. Measurements made on June 15, 2019 showed a decreased on the mass of the salamanders for the chemical treatment using diving beetles as predator ( $df = 1$ ,  $F = 9.313$ ,  $p\text{-value} = 0.0101$ ; Fig. 2a; Table 2), however, this result might not be related to the treatment or the predators since this was the first day of measurement. Interactions between larvae while they were on separate tanks could triggered this as a response to competition for space in the tank. Dragonfly nymphs' chemical treatments exhibit a decreased in mean length of the larvae on June 30, 2019 ( $df = 1$ ,  $F = 5.524$ ,  $p\text{-value} = 0.0385$ ; Fig. 3b; Table 2) that can be related to the presence of kairomones released by the predators. Overall, larvae seemed to have a more active respond to the chemical treatments for both diving beetles and dragonfly nymphs.



The Pos-Hoc analysis (Table 3) showed an increased in the mean body mass for the no chemical treatments in diving beetles (difference = 0.0106875, p-value = 0.0100513) while revealed a decreased in the mean length in the chemical treatments for the dragonfly nymphs (difference = -0.5514668, p-value = 0.0388775).

The survival tests showed that there was no significant difference between the treatments and the predators (Table 4). Finally, behavior was tested in a general way to see how the larvae react to the presence of a predator and no significant difference was found between refuge types and open area (X-squared = 4.4, df = 6, p-value = 0.6227; Table 5). Larvae seemed to have no preference for a place to hide.

## **Discussion**

Our results did not support the hypothesis that *Ambystoma maculatum* larvae respond differently to different cue-types. Overall the larvae in predator treatments were smaller in both mass and length, which contradicts our prediction. However, we did observe that the larvae have a more active respond to the exposure of chemical cues in the treatments. The most prevalent behavioral pattern was to reduce their activity and seek for refuge alternatives without having any preference. The rates of survival did not vary among treatments. Understanding these fluctuations in anti-predator responses is an important part of understanding how systems are governed both by predation and by the responses it receives from prey.

In aquatic environments, prey usually rely on chemical cues as the primary signal to recognize the riskiness of their surroundings (Shelton 2016). In order to optimize the tradeoff between costs and benefits, the preys need to be able to recognize specific predators and the risk they impose (Albecker and Vance-Chalcraft 2015). However, we found that the larvae had the same response for both diving beetles and dragonfly nymphs and in both cases, they tended to

reduce their mass and length as a response to the chemical cues. In contrast, Mathis and Vincent (2000) found that newt larvae were able to distinguish between heterospecifics that were predatory and nonpredatory when only chemical cues were available. However, this difference could be attributed to food that was provided to the predators. Larvae have stronger responses to cues released by predators that are fed conspecifics (or at least closely-related heterospecifics), and our predators were fed black field ants. Because ants and salamander larvae do not cross paths during this life stage, and because of the vast taxonomic difference between ants and salamanders, our larvae would have only been exposed to kairomones. Roberts and García de Leaniz (2011) examined the role of diet-released chemical cues in facilitating predator recognition and promoting antipredator responses on juvenile *Salmo salar* and found that no antipredator behavior was developed in treatments where the predators were fed with non-salmon diet, but the treatments where the predators were fed with salmon diet did have strong behavioral changes- spatial avoidance, reduce activity and increasing ventilation (Rajchard 2013). Not being able to identify diet cues from the predators could lead to not exhibiting full predator defenses.

We observed that larvae reduced their activity but did not increase the refuge use as a way to prevent predators from noticing their presence. However, these defensive behaviors may eventually alter their feeding patterns (Steiner and Pfeiffer 2007). We noticed that the larvae did not consume the *Daphnia* when fed unless it was directly in front of them, potentially to make as little movement as possible since this would incur an energy expenditure which they are already investing to stay alive. Svanbäck et al. (2017) studied the interactions between predation risk and food ration on behavior and morphology on *Perca fluviatilis* and found that they reduced activity with the presence of the predator and when high levels of food were available as a way to avoid predation since it gave them the chance to save energy and, hence, invest in development.

Investing in these strategies and leaving behind an essential part of their development and survival, feeding, can be one of the causes that contribute to slow their growth and developmental rates. Maurer and Sih (1996) suggested that an increase in activity might drive rapid feeding, growth, and development. High activity has an energetic cost and in terms of survival, larvae should choose between survival through investing in predator avoidance or rapid growth and development (Maurer and Sih 1996). However, Werner (1991) found evidence of increased competitive ability of *Lithobates catesbeianus* larvae and *Lithobates clamitans* larvae due to higher activity in bullfrogs when the predator, *Anax junius*, was not present. *Lithobates clamitans* exhibit slower growth rates than *Lithobates catesbeianus*, but in the presence of the predator they both reduced their activity and changed their spatial use. The increase in refuge use could allow for reduced encounter rates with predators and the reduced probability of detection (Maurer and Sih 1996). Sih et al. (1988) was capable to demonstrate that stream salamander larvae species, *Ambystoma texanum*, increase their refuge use and reduce both emergence rates and activity to avoid been eaten. However, we did not find an increase in refuge and this could be related to the lack of predation recognition.

Spotted salamander's larvae have the capacity to respond uniquely to chemical cues from different predators and according to their identities develop certain strategies for survival (Rack 2016; Urban 2010; Urban 2008). These responses can be genetically innate or learned but the expression of them depends on the exposure to the predation risk (Albecker and Vance-Chalcraft 2015). In both cases we observed that the larvae reduce their activity when they were exposed to both chemical and visual cues so this could be caused by an innate response. Epp and Gabor (2008) studied the both innate and learned predator recognition using chemical cues in *Eurycea nana* and found that the larvae reduced their activity when chemical cues of a native fish

predator was presence. They emphasized the fact that this behavior pattern was exhibited by many other amphibian prey species and, therefore, they had evidence to conclude that there was an innate component in the predator recognition in *E. nana*. However, we did not notice that in our study the larvae change their behavior according to the predator identity. Identifying predators' cues can be related to learned responses through the exposure of attacks to conspecifics, direct contact, or social learning (Ferrari et al. 2009). In aquatic prey, attacks on conspecifics are a widespread mode of learning because it allows them to pair the injured animal cues with the odor or sight of a novel predator (Ferrari et al. 2009). Ferrari et al. (2007) found that *Pimephales promelas* were capable to chemically generalize anti-predator responses between closely related predator species, *Salvelinus namaycush* and Salmonidae. However, the predators used are not related at all and that indicates that in order to identify with certainty which predator is facing a prey, they need to learn more chemical cues, to learn more chemical signals, in addition to the kairomones, to be able to develop specific defenses against predators.

Further studies could be conducted to determine how the *Ambystoma maculatum* behave and react in the presence of different predators and if these responses are due to innate or learned behaviors. This could be done by comparing larvae hatched in the laboratory and others hatched in the vernal ponds. Other potential extensions that can be applied to this experiment is evaluating the levels of cannibalism during the larval stage to see if there is an influence between being born in captivity and their natural habitats. Predators could be included in this project to see how the level of stress and cues release by them can influence the both anti-predator and cannibalistic behaviors. Another study to be conducted could involve the predation risk behavior between adults and larvae so see if there are tradeoffs from the behavior acquired or learned in the larval state. Through this project we could reaffirm the importance of development strategies

to survive. The chemical cues play an important role in the aquatic systems since the prey has more accessibility to them. However, the animals that make up each system are based on the use of different types of signals to survive and understanding the diversity of responses that exists is an important factor to understand, since predation influences the ecology, behavior and evolution of animal species.

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## Tables

Table 1. Shapiro-Wilk test results for normality.

Predator	Day	Mass or Length	p-value
Diving beetle	June 15, 2019	M	<b>0.06587 *</b>
Diving beetle	June 15, 2019	L	0.4575
Diving beetle	June 30, 2019	M	0.06032
Diving beetle	June 30, 2019	L	0.5768
Diving beetle	July 13, 2019	M	0.1986
Diving beetle	July 13, 2019	L	0.1138
Dragonfly nymph	June 15, 2019	M	<b>0.2967 *</b>
Dragonfly nymph	June 15, 2019	L	0.6922
Dragonfly nymph	June 30, 2019	M	0.7762
Dragonfly nymph	June 30, 2019	L	0.5977
Dragonfly nymph	July 13, 2019	M	0.9542
Dragonfly nymph	July 13, 2019	L	0.7586

<sup>1</sup>P-values with \* were normalized using log<sub>10</sub> function. The original values were 0.04055 and 0.3162 respectively.

Table 2. Measurements for mass and length of the salamanders per day of measurement.

Predator	Day	Treatment	Mass or Length	df	F value	p-value
Diving beetle	June 15, 2019	V	M	1	0.724	0.4116
Diving beetle	June 15, 2019	C	M	1	9.313	<b>0.0101 *</b>
Diving beetle	June 15, 2019	V:C	M	1	0.168	0.6887
Diving beetle	June 15, 2019	V	L	1	1.141	0.306
Diving beetle	June 15, 2019	C	L	1	1.399	0.260
Diving beetle	June 15, 2019	V:C	L	1	1.491	0.246
Diving beetle	June 30, 2019	V	M	1	1.344	0.273
Diving beetle	June 30, 2019	C	M	1	1.527	0.245
Diving beetle	June 30, 2019	V:C	M	1	0.095	0.765
Diving beetle	June 30, 2019	V	L	1	0.005	0.945
Diving beetle	June 30, 2019	C	L	1	0.229	0.642
Diving beetle	June 30, 2019	V:C	L	1	0.001	0.972
Diving beetle	July 13, 2019	V	M	1	0.000	0.9883
Diving beetle	July 13, 2019	C	M	1	4.558	0.0997
Diving beetle	July 13, 2019	V:C	M	1	5.800	0.0737
Diving beetle	July 13, 2019	V	L	1	0.188	0.687
Diving beetle	July 13, 2019	C	L	1	0.292	0.617
Diving beetle	July 13, 2019	V:C	L	1	1.594	0.275
Dragonfly nymph	June 15, 2019	V	M	1	0.650	0.436
Dragonfly nymph	June 15, 2019	C	M	1	1.102	0.314
Dragonfly nymph	June 15, 2019	V:C	M	1	2.057	0.177

Dragonfly nymph	June 15, 2019	V	L	1	0.009	0.926
Dragonfly nymph	June 15, 2019	C	L	1	0.955	0.348
Dragonfly nymph	June 15, 2019	V:C	L	1	0.057	0.816
Dragonfly nymph	June 30, 2019	V	M	1	0.114	0.742
Dragonfly nymph	June 30, 2019	C	M	1	1.480	0.249
Dragonfly nymph	June 30, 2019	V:C	M	1	0.024	0.879
Dragonfly nymph	June 30, 2019	V	L	1	1.740	0.2139
Dragonfly nymph	June 30, 2019	C	L	1	5.524	<b>0.0385 *</b>
Dragonfly nymph	July 30, 2019	V:C	L	1	0.010	0.9232
Dragonfly nymph	July 13, 2019	V	M	1	56.067	0.0845
Dragonfly nymph	July 13, 2019	C	M	1	17.190	0.1507
Dragonfly nymph	July 13, 2019	V:C	M	1	1.921	0.3979
Dragonfly nymph	July 13, 2019	V	L	1	0.097	0.807
Dragonfly nymph	July 13, 2019	C	L	1	0.070	0.836
Dragonfly nymph	July 13, 2019	V:C	L	1	0.127	0.782

<sup>1</sup>Visual (V), chemical (C), visual:chemical (V:C), mass (M), length (L).

<sup>2</sup>P-values with \* show a significant difference.

Table 3. Pos-Hoc Analysis with Tukey test on significant values.

Predator and Day	Treatment	Difference	Lower	Upper	P-value
Diving beetle June 15, 2019	V	V-NV 0.002979167	-0.004651135	0.01060947	0.411593
Diving beetle June 15, 2019	C	NC-C 0.0106875	0.003057198	0.0183178	0.0100513
Dragonfly nymph June 30, 2019	V	V-NV -0.3102976	-0.8280552	0.2074599	0.2139438
Dragonfly nymph June 30, 2019	C	NC-C -0.5514668	-1.069224	-0.03370927	0.0388775

<sup>1</sup>Tukey's HSD was run for mass in diving beetles results and for length in the dragonfly nymphs.

<sup>2</sup>Visual (V); chemical (C).

Table 4. Survival test at the end of the experiment.

Predator	Day	Treatment	df	F value	p-value
Diving beetle	July 13, 2019	V	1	2.348	0.151
Diving beetle	July 13, 2019	C	1	1.043	0.327
Diving beetle	July 13, 2019	V:C	1	1.043	0.327
Dragonfly nymphs	July 13, 2019	V	1	0.492	0.498
Dragonfly nymphs	July 13, 2019	C	1	0.567	0.467
Dragonfly nymphs	July 13, 2019	V:C	1	0.000	1.000

<sup>1</sup>Visual (V), chemical (C), visual:chemical (V:C)

Table 5. Behavioral trails conducted using dragonfly nymphs' treatments.

<b>Predator</b>	<b>X-squared</b>	<b>df</b>	<b>p-value</b>
Dragonfly nymphs	4.4	6	0.6227

<sup>1</sup>Only dragonfly nymphs were used because we wanted to look behavior in general and not specificity according to the predator identity.

Figures

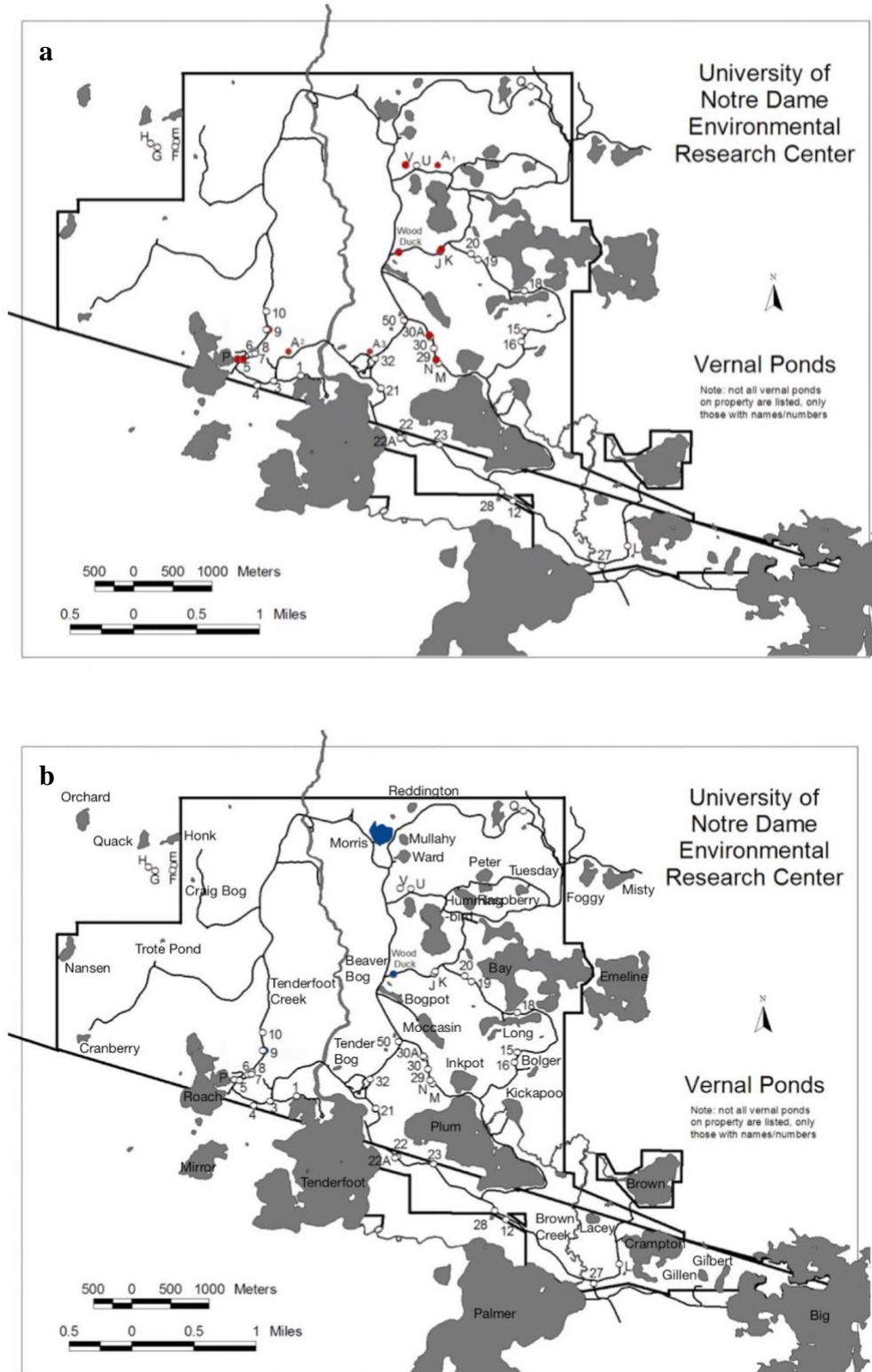
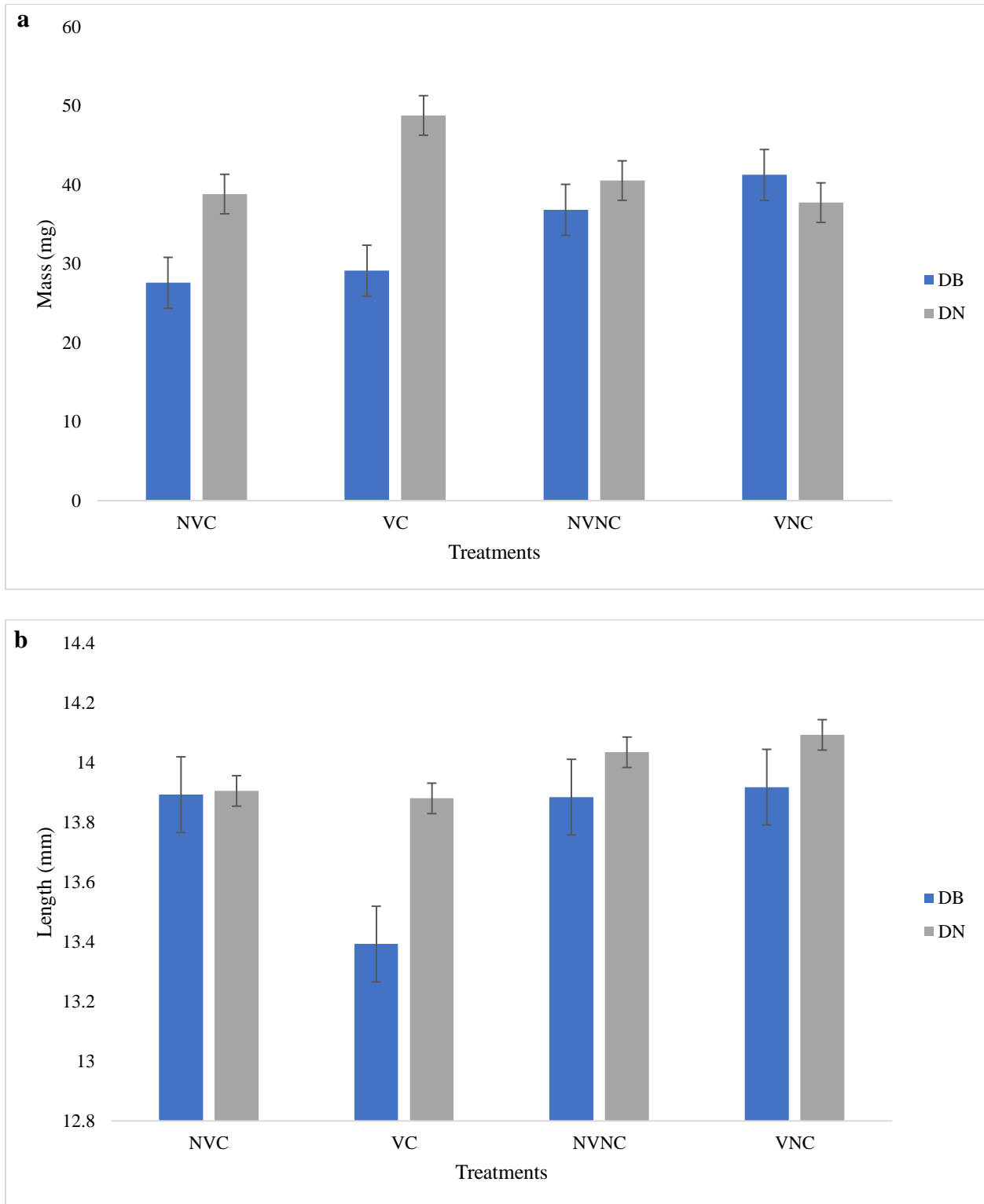
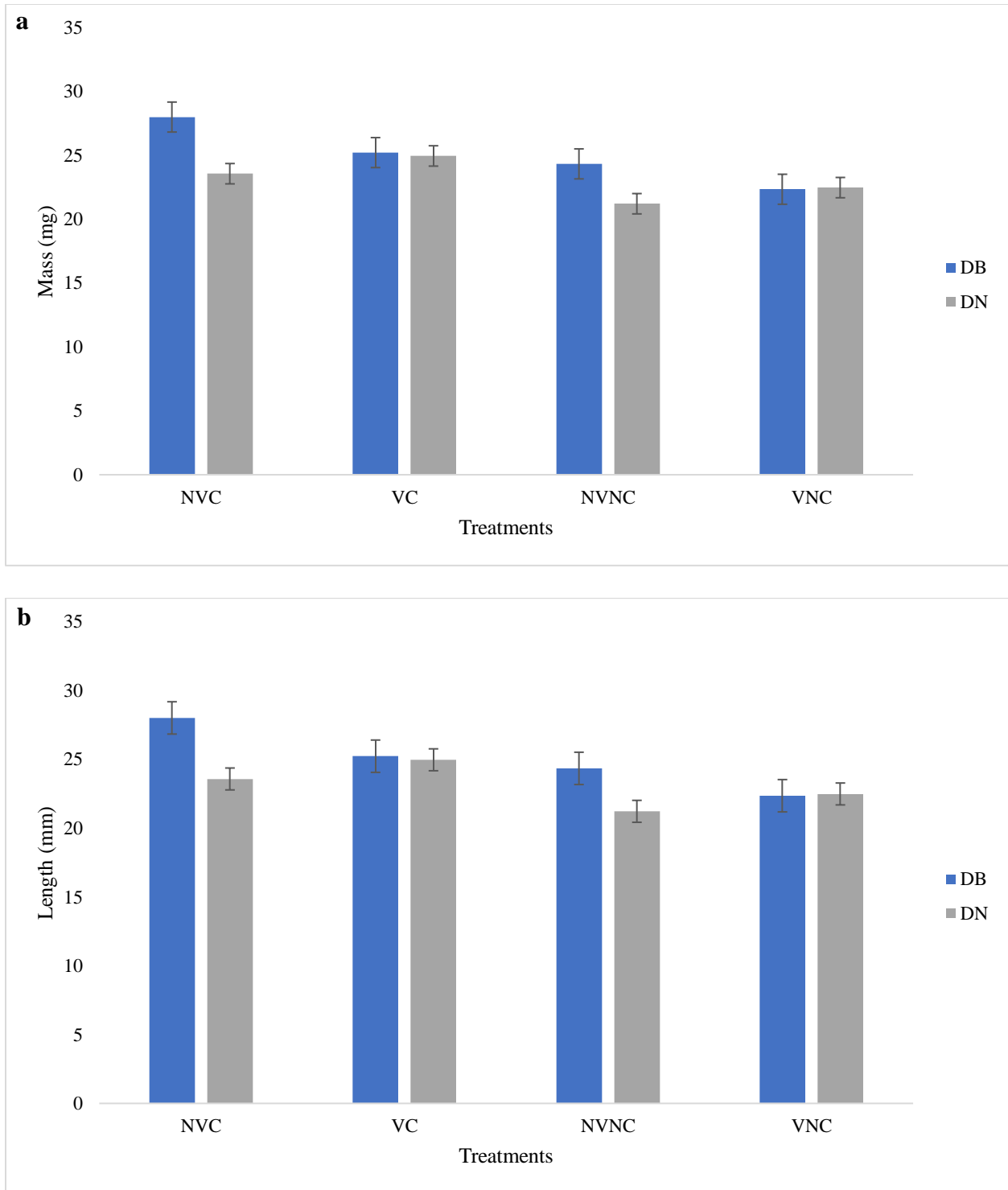


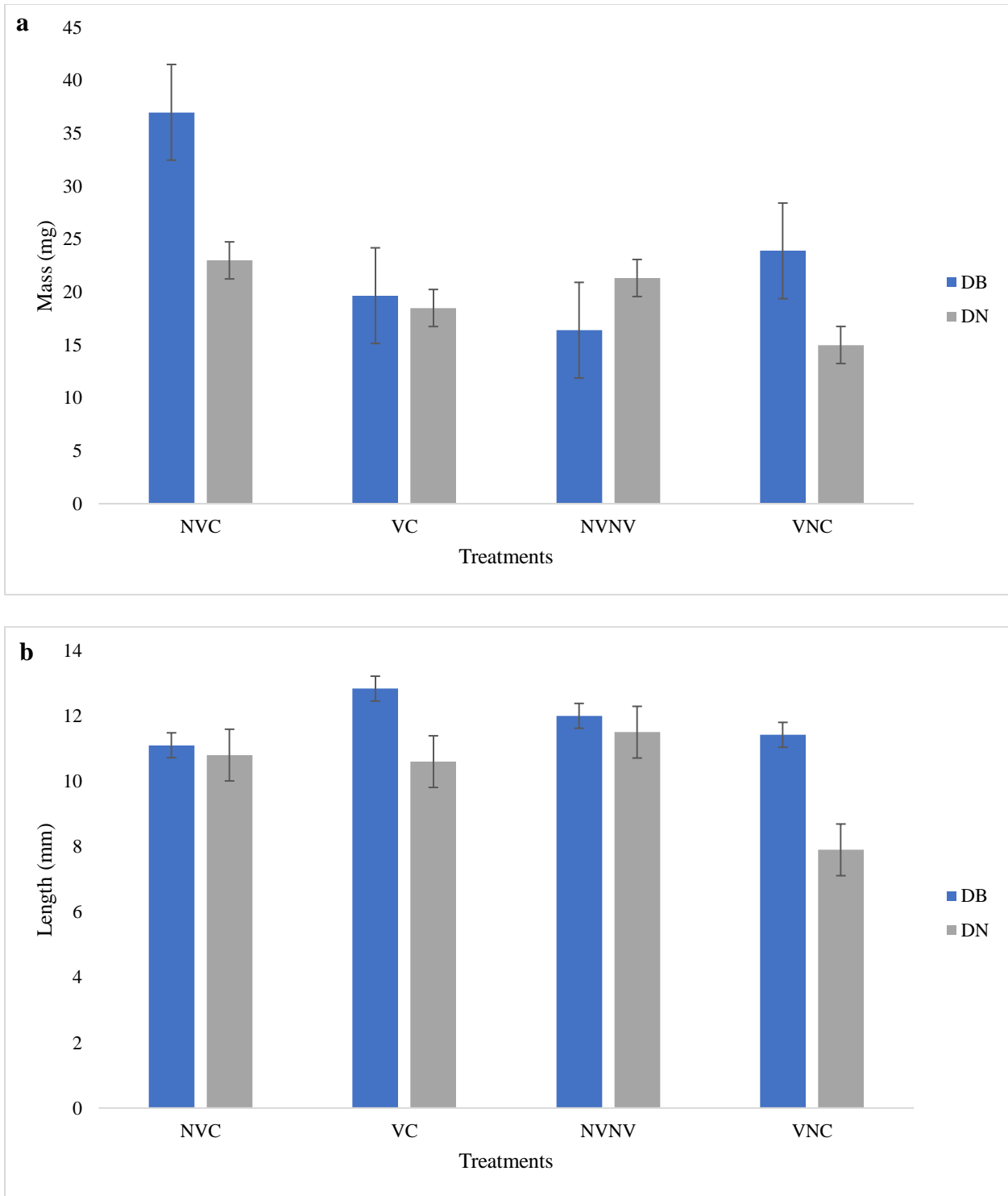
Figure 1. Areas where egg masses and predators were collected **a** eggs masses areas **b** predators areas. Ponds A<sub>1</sub>, A<sub>2</sub>, and A<sub>3</sub> did not appear in the original map. They were marked by us.



*Figure 2.* Mass and length (mean  $\pm$  SD) measurements done on June 15, 2019 **a** masses averages for the treatments of both diving beetles (DB) and dragonfly nymphs (DN) **b** length averages for both diving beetles and dragonfly nymphs. The abbreviations in the treatments correspond to non-visual/chemical (NVC), visual/chemical (VC), non-visual/non-chemical (NVNC), and visual/non-chemical (VNC). There was a significant difference in mass for the diving beetle in the chemical treatments (p-value = 0.0101).



*Figure 3.* Mass and length (mean  $\pm$  SD) measurements done on June 30, 2019 **a** masses averages and for both diving beetles (DB) and dragonfly nymphs (DN) **b** length averages for both diving beetles and dragonfly nymphs. The abbreviations in the treatments correspond to non-visual/chemical (NVC), visual/chemical (VC), non-visual/non-chemical (NVNC), and visual/non-chemical (VNC). There was a significant difference for length in dragonfly nymphs for the chemical treatments (p-value = 0.0385).



*Figure 4.* Mass and length (mean  $\pm$  SD) measurements done on July 13, 2019 **a** masses averages and for both diving beetles and dragonfly nymphs **b** length averages for both diving beetles and dragonfly nymphs. The abbreviations in the treatments correspond to non-visual/chemical (NVC), visual/chemical (VC), non-visual/non-chemical (NVNC), and visual/non-chemical (VNC). There was no significant difference between mass and length for any of the treatments.



**Appendix**

Table S1. Collection of eggs masses, dragonfly nymphs, and diving beetles in each pond sampled.

<b>Area</b>	<b>Egg masses</b>	<b>Dragonflies nymphs</b>	<b>Diving water beetles</b>
Pool P	1	0	0
Pool 5	1	0	0
Pool 30A	5	0	0
Pool N	1	0	0
Pool J	2	0	0
Pool K	2	0	0
Wood Duck	2	26	11
Pool V	1	0	0
Pool A <sub>1</sub>	0	0	0
Pool A <sub>2</sub>	2	0	0
Pool A <sub>3</sub>	1	0	0
Pool 9	1	11	14
Morris	0	12	0

<sup>1</sup>Pool A<sub>1</sub> was used to collect tadpoles

Table S2. Range of hatching per day of each egg masses.

<b>Day</b>	<b>Brood</b>	<b>Number of larvae</b>
June 1, 2019	P	3
June 1, 2019	30A	1
June 1, 2019	Wood Duck	60
June 1, 2019	K	18
June 1, 2019	V	5
June 1, 2019	9	18
June 2, 2019	Wood Duck	7
June 2, 2019	N	2
June 2, 2019	K	3
June 4, 2019	J	9
June 4, 2019	K	9
June 4, 2019	N	9
June 4, 2019	P	1
June 4, 2019	V	167
June 5, 2019	Wood Duck	15
June 5, 2019	N	18
June 5, 2019	5	23
June 5, 2019	P	3
June 5, 2019	A <sub>2</sub>	47
June 6, 2019	V	3
June 6, 2019	Wood Duck	5

June 6, 2019	A <sub>2</sub>	20
June 7, 2019	Wood Duck	1
June 7, 2019	5	2
June 7, 2019	A <sub>2</sub>	18
June 9, 2019	A <sub>2</sub>	3
June 9, 2019	A <sub>3</sub>	14
June 9, 2019	5	5
June 9, 2019	J	1

Table S3. Body mass and length measurements estimated on June 15, 2019, June 30, 2019, and July 13, 2019.

Tank Number	Predator	Treatment	Brood	Day	Mass (mg)	Length (mm)
1	DB	VC	J	06-15-19	0.028	14.2
1	DB	VC	J	06-15-19	0.044	14.6
1	DB	VC	J	06-15-19	0.023	14.9
1	DB	VC	J	06-15-19	0.051	13.9
1	DB	VC	J	06-15-19	0.052	14.1
1	DB	VC	J	06-15-19	0.054	14.2
2	DB	VC	A <sub>2</sub>	06-15-19	0.02	13.5
2	DB	VC	A <sub>2</sub>	06-15-19	0.028	13.7
2	DB	VC	A <sub>2</sub>	06-15-19	0.016	12.5
2	DB	VC	A <sub>2</sub>	06-15-19	0.015	14
2	DB	VC	A <sub>2</sub>	06-15-19	0.029	9.3
2	DB	VC	A <sub>2</sub>	06-15-19	0.033	14.3
3	DB	VC	N	06-15-19	0.02	13.9
3	DB	VC	N	06-15-19	0.024	13.1
3	DB	VC	N	06-15-19	0.039	12.9
3	DB	VC	N	06-15-19	0.019	12.3
3	DB	VC	N	06-15-19	0.019	13
3	DB	VC	N	06-15-19	0.038	13.7
4	DB	VC	WoodDuck	06-15-19	0.023	13.3
4	DB	VC	WoodDuck	06-15-19	0.02	13.5
4	DB	VC	WoodDuck	06-15-19	0.019	13
4	DB	VC	WoodDuck	06-15-19	0.026	13.4
4	DB	VC	WoodDuck	06-15-19	0.022	13.1
4	DB	VC	WoodDuck	06-15-19	0.037	13
1	DB	NVC	A <sub>2</sub>	06-15-19	0.027	13.4
1	DB	NVC	A <sub>2</sub>	06-15-19	0.025	14.7
1	DB	NVC	A <sub>2</sub>	06-15-19	0.028	14.2

1	DB	NVC	A2	06-15-19	0.023	13.8
1	DB	NVC	A2	06-15-19	0.019	12.7
1	DB	NVC	A2	06-15-19	0.042	14.7
2	DB	NVC	WoodDuck	06-15-19	0.024	14.3
2	DB	NVC	WoodDuck	06-15-19	0.023	13.2
2	DB	NVC	WoodDuck	06-15-19	0.017	13.6
2	DB	NVC	WoodDuck	06-15-19	0.022	13.8
2	DB	NVC	WoodDuck	06-15-19	0.034	14.1
2	DB	NVC	WoodDuck	06-15-19	0.037	14.4
3	DB	NVC	N	06-15-19	0.063	14
3	DB	NVC	N	06-15-19	0.02	14
3	DB	NVC	N	06-15-19	0.02	13.5
3	DB	NVC	N	06-15-19	0.023	13.5
3	DB	NVC	N	06-15-19	0.022	13.8
3	DB	NVC	N	06-15-19	0.02	13.4
4	DB	NVC	J	06-15-19	0.019	13.7
4	DB	NVC	J	06-15-19	0.028	13.8
4	DB	NVC	J	06-15-19	0.044	14.2
4	DB	NVC	J	06-15-19	0.026	14.9
4	DB	NVC	J	06-15-19	0.024	14
4	DB	NVC	J	06-15-19	0.032	13.7
1	DB	VNC	A2	06-15-19	0.039	14.3
1	DB	VNC	A2	06-15-19	0.071	14.6
1	DB	VNC	A2	06-15-19	0.058	12.5
1	DB	VNC	A2	06-15-19	0.043	14.3
1	DB	VNC	A2	06-15-19	0.036	13.6
1	DB	VNC	A2	06-15-19	0.045	13.8
2	DB	VNC	N	06-15-19	0.033	13.6
2	DB	VNC	N	06-15-19	0.019	13.2
2	DB	VNC	N	06-15-19	0.029	13.8
2	DB	VNC	N	06-15-19	0.037	13.7
2	DB	VNC	N	06-15-19	0.026	14
3	DB	VNC	WoodDuck	06-15-19	0.041	14
3	DB	VNC	WoodDuck	06-15-19	0.039	13.9
3	DB	VNC	WoodDuck	06-15-19	0.063	14.2
3	DB	VNC	WoodDuck	06-15-19	0.035	13.6
3	DB	VNC	WoodDuck	06-15-19	0.055	13.8
3	DB	VNC	WoodDuck	06-15-19	0.024	12.9
4	DB	VNC	J	06-15-19	0.029	14.5

4	DB	VNC	J	06-15-19	0.051	15.2
4	DB	VNC	J	06-15-19	0.065	14
4	DB	VNC	J	06-15-19	0.041	13.9
4	DB	VNC	J	06-15-19	0.051	14.2
4	DB	VNC	J	06-15-19	0.042	14.5
1	DB	NVNC	J	06-15-19	0.025	14.5
1	DB	NVNC	J	06-15-19	0.029	14.3
1	DB	NVNC	J	06-15-19	0.048	14
1	DB	NVNC	J	06-15-19	0.048	13.9
1	DB	NVNC	J	06-15-19	0.034	14.6
1	DB	NVNC	J	06-15-19	0.052	14.5
2	DB	NVNC	WoodDuck	06-15-19	0.027	13.9
2	DB	NVNC	WoodDuck	06-15-19	0.028	13
2	DB	NVNC	WoodDuck	06-15-19	0.02	14.5
2	DB	NVNC	WoodDuck	06-15-19	0.045	12.6
2	DB	NVNC	WoodDuck	06-15-19	0.036	12.5
2	DB	NVNC	WoodDuck	06-15-19	0.025	13.6
3	DB	NVNC	A2	06-15-19	0.032	14.8
3	DB	NVNC	A2	06-15-19	0.072	14.5
3	DB	NVNC	A2	06-15-19	0.028	14.4
3	DB	NVNC	A2	06-15-19	0.025	14.2
3	DB	NVNC	A2	06-15-19	0.02	13.6
3	DB	NVNC	A2	06-15-19	0.042	14.3
4	DB	NVNC	N	06-15-19	0.031	13.8
4	DB	NVNC	N	06-15-19	0.04	13.3
4	DB	NVNC	N	06-15-19	0.039	13.9
4	DB	NVNC	N	06-15-19	0.035	12.8
4	DB	NVNC	N	06-15-19	0.058	13.7
4	DB	NVNC	N	06-15-19	0.045	14
1	DN	VC	V	06-15-19	0.071	14.4
1	DN	VC	V	06-15-19	0.072	14
1	DN	VC	V	06-15-19	0.078	14.5
1	DN	VC	V	06-15-19	0.045	14.1
1	DN	VC	V	06-15-19	0.046	14.1
1	DN	VC	V	06-15-19	0.087	10.4
2	DN	VC	WoodDuck	06-15-19	0.032	13.7
2	DN	VC	WoodDuck	06-15-19	0.077	14.3
2	DN	VC	WoodDuck	06-15-19	0.076	14.2
2	DN	VC	WoodDuck	06-15-19	0.05	11.4

2	DN	VC	WoodDuck	06-15-19	0.039	13.2
2	DN	VC	WoodDuck	06-15-19	0.051	14.2
3	DN	VC	J	06-15-19	0.025	15
3	DN	VC	J	06-15-19	0.038	14
3	DN	VC	J	06-15-19	0.036	14.2
3	DN	VC	J	06-15-19	0.051	14.5
3	DN	VC	J	06-15-19	0.03	14.1
3	DN	VC	J	06-15-19	0.027	14.6
4	DN	VC	A2	06-15-19	0.05	14.4
4	DN	VC	A2	06-15-19	0.023	13
4	DN	VC	A2	06-15-19	0.032	13.4
4	DN	VC	A2	06-15-19	0.038	14.6
4	DN	VC	A2	06-15-19	0.034	14.9
4	DN	VC	A2	06-15-19	0.063	13.9
1	DN	NVC	J	06-15-19	0.028	14.4
1	DN	NVC	J	06-15-19	0.03	15
1	DN	NVC	J	06-15-19	0.033	14.1
1	DN	NVC	J	06-15-19	0.044	14.2
1	DN	NVC	J	06-15-19	0.037	13.8
1	DN	NVC	J	06-15-19	0.048	14
2	DN	NVC	A2	06-15-19	0.047	13.9
2	DN	NVC	A2	06-15-19	0.065	14.4
2	DN	NVC	A2	06-15-19	0.038	13.3
2	DN	NVC	A2	06-15-19	0.057	14.2
2	DN	NVC	A2	06-15-19	0.04	13.1
2	DN	NVC	A2	06-15-19	0.043	14.5
3	DN	NVC	WoodDuck	06-15-19	0.033	14.2
3	DN	NVC	WoodDuck	06-15-19	0.037	14.5
3	DN	NVC	WoodDuck	06-15-19	0.028	13.3
3	DN	NVC	WoodDuck	06-15-19	0.023	12.6
3	DN	NVC	WoodDuck	06-15-19	0.039	13.8
3	DN	NVC	WoodDuck	06-15-19	0.028	13.8
4	DN	NVC	V	06-15-19	0.026	13.7
4	DN	NVC	V	06-15-19	0.039	13.8
4	DN	NVC	V	06-15-19	0.028	13.8
4	DN	NVC	V	06-15-19	0.039	13.9
4	DN	NVC	V	06-15-19	0.034	14.1
4	DN	NVC	V	06-15-19	0.068	13.3
1	DN	VNC	A2	06-15-19	0.028	14.4

1	DN	VNC	A2	06-15-19	0.04	14.1
1	DN	VNC	A2	06-15-19	0.025	14.2
1	DN	VNC	A2	06-15-19	0.039	14
1	DN	VNC	A2	06-15-19	0.062	12.6
1	DN	VNC	A2	06-15-19	0.033	13.8
2	DN	VNC	J	06-15-19	0.02	14.4
2	DN	VNC	J	06-15-19	0.025	14.8
2	DN	VNC	J	06-15-19	0.038	15.1
2	DN	VNC	J	06-15-19	0.034	14.1
2	DN	VNC	J	06-15-19	0.073	14.9
2	DN	VNC	J	06-15-19	0.083	14.7
3	DN	VNC	WoodDuck	06-15-19	0.026	12.9
3	DN	VNC	WoodDuck	06-15-19	0.02	14.2
3	DN	VNC	WoodDuck	06-15-19	0.054	14.7
3	DN	VNC	WoodDuck	06-15-19	0.033	14.4
3	DN	VNC	WoodDuck	06-15-19	0.037	13.9
3	DN	VNC	WoodDuck	06-15-19	0.026	14.1
4	DN	VNC	V	06-15-19	0.029	12.9
4	DN	VNC	V	06-15-19	0.019	14.7
4	DN	VNC	V	06-15-19	0.03	13.9
4	DN	VNC	V	06-15-19	0.076	13.5
4	DN	VNC	V	06-15-19	0.038	14.4
1	DN	NVNC	A2	06-15-19	0.043	14.4
1	DN	NVNC	A2	06-15-19	0.027	13.2
1	DN	NVNC	A2	06-15-19	0.022	13.9
1	DN	NVNC	A2	06-15-19	0.061	14.4
1	DN	NVNC	A2	06-15-19	0.023	14
1	DN	NVNC	A2	06-15-19	0.024	13.8
2	DN	NVNC	V	06-15-19	0.055	13.4
2	DN	NVNC	V	06-15-19	0.072	13.7
2	DN	NVNC	V	06-15-19	0.04	13.3
2	DN	NVNC	V	06-15-19	0.026	14.1
2	DN	NVNC	V	06-15-19	0.051	13.6
2	DN	NVNC	V	06-15-19	0.023	13.9
3	DN	NVNC	J	06-15-19	0.024	14.5
3	DN	NVNC	J	06-15-19	0.034	14.3
3	DN	NVNC	J	06-15-19	0.055	14.5
3	DN	NVNC	J	06-15-19	0.059	14.4
3	DN	NVNC	J	06-15-19	0.026	14

3	DN	NVNC	J	06-15-19	0.044	14.8
4	DN	NVNC	WoodDuck	06-15-19	0.06	14
4	DN	NVNC	WoodDuck	06-15-19	0.038	14.7
4	DN	NVNC	WoodDuck	06-15-19	0.059	13.3
4	DN	NVNC	WoodDuck	06-15-19	0.022	13.5
4	DN	NVNC	WoodDuck	06-15-19	0.034	14.5
4	DN	NVNC	WoodDuck	06-15-19	0.051	14.6
1	DB	VC	J	06-30-19	0.019	12
1	DB	VC	J	06-30-19	0.045	11.2
1	DB	VC	J	06-30-19	0.017	12.2
1	DB	VC	J	06-30-19	0.016	12.3
1	DB	VC	J	06-30-19	0.025	12.5
2	DB	VC	A2	06-30-19	0.016	12.8
2	DB	VC	A2	06-30-19	0.014	13
2	DB	VC	A2	06-30-19	0.022	12.5
2	DB	VC	A2	06-30-19	0.02	13.1
2	DB	VC	A2	06-30-19	0.03	11
2	DB	VC	A2	06-30-19	0.027	12.2
3	DB	VC	WoodDuck	06-30-19	0.019	13.3
3	DB	VC	WoodDuck	06-30-19	0.026	13.1
3	DB	VC	WoodDuck	06-30-19	0.037	13.2
3	DB	VC	WoodDuck	06-30-19	0.022	12.5
4	DB	VC	J	06-30-19	0.036	12.6
4	DB	VC	J	06-30-19	0.027	13.5
4	DB	VC	J	06-30-19	0.062	13.7
4	DB	VC	J	06-30-19	0.019	12.5
4	DB	VC	J	06-30-19	0.02	13.2
4	DB	VC	J	06-30-19	0.025	14.3
1	DB	NVC	N	06-30-19	0.033	11.5
1	DB	NVC	N	06-30-19	0.035	11.2
1	DB	NVC	N	06-30-19	0.035	12.6
1	DB	NVC	N	06-30-19	0.05	12.4
1	DB	NVC	N	06-30-19	0.03	13.4
1	DB	NVC	N	06-30-19	0.032	13.3
2	DB	NVC	A2	06-30-19	0.024	12.6
2	DB	NVC	A2	06-30-19	0.025	12.4
2	DB	NVC	A2	06-30-19	0.064	13.3
2	DB	NVC	A2	06-30-19	0.017	14
2	DB	NVC	A2	06-30-19	0.016	12

2	DB	NVC	A2	06-30-19	0.019	11
3	DB	NVC	WoodDuck	06-30-19	0.02	13.5
3	DB	NVC	WoodDuck	06-30-19	0.03	12.8
3	DB	NVC	WoodDuck	06-30-19	0.019	13.3
3	DB	NVC	WoodDuck	06-30-19	0.02	13.1
3	DB	NVC	WoodDuck	06-30-19	0.017	13.3
1	DB	VNC	A2	06-30-19	0.019	14.8
1	DB	VNC	A2	06-30-19	0.023	13.6
1	DB	VNC	A2	06-30-19	0.022	14
1	DB	VNC	A2	06-30-19	0.02	12.4
1	DB	VNC	A2	06-30-19	0.025	14.1
2	DB	VNC	WoodDuck	06-30-19	0.015	11.4
2	DB	VNC	WoodDuck	06-30-19	0.032	12.2
2	DB	VNC	WoodDuck	06-30-19	0.02	12.6
2	DB	VNC	WoodDuck	06-30-19	0.023	11.8
2	DB	VNC	WoodDuck	06-30-19	0.013	11.6
3	DB	VNC	N	06-30-19	0.022	13.5
3	DB	VNC	N	06-30-19	0.015	12.9
3	DB	VNC	N	06-30-19	0.022	13
3	DB	VNC	N	06-30-19	0.021	13.2
4	DB	VNC	J	06-30-19	0.038	13.2
4	DB	VNC	J	06-30-19	0.028	13.4
4	DB	VNC	J	06-30-19	0.047	11.5
4	DB	VNC	J	06-30-19	0.017	12.9
4	DB	VNC	J	06-30-19	0.022	12.8
4	DB	VNC	J	06-30-19	0.016	13
1	DB	NVNC	N	06-30-19	0.036	10.3
1	DB	NVNC	N	06-30-19	0.017	12.5
1	DB	NVNC	N	06-30-19	0.019	12.5
1	DB	NVNC	N	06-30-19	0.017	12.3
1	DB	NVNC	N	06-30-19	0.023	13.4
1	DB	NVNC	N	06-30-19	0.025	11.9
2	DB	NVNC	WoodDuck	06-30-19	0.022	12.2
2	DB	NVNC	WoodDuck	06-30-19	0.026	13.2
2	DB	NVNC	WoodDuck	06-30-19	0.023	12.4
2	DB	NVNC	WoodDuck	06-30-19	0.025	11.6
2	DB	NVNC	WoodDuck	06-30-19	0.02	12.2
2	DB	NVNC	WoodDuck	06-30-19	0.016	12.2
3	DB	NVNC	A2	06-30-19	0.027	13.2



3	DB	NVNC	A2	06-30-19	0.025	13
3	DB	NVNC	A2	06-30-19	0.02	13.3
3	DB	NVNC	A2	06-30-19	0.025	14.1
3	DB	NVNC	A2	06-30-19	0.028	14
3	DB	NVNC	A2	06-30-19	0.033	13.5
4	DB	NVNC	J	06-30-19	0.03	13.9
4	DB	NVNC	J	06-30-19	0.02	13.2
4	DB	NVNC	J	06-30-19	0.023	12.7
4	DB	NVNC	J	06-30-19	0.025	14
4	DB	NVNC	J	06-30-19	0.037	13.7
4	DB	NVNC	J	06-30-19	0.022	13.5
1	DN	VC	V	06-30-19	0.03	11.2
1	DN	VC	V	06-30-19	0.039	13.1
1	DN	VC	V	06-30-19	0.022	13.5
1	DN	VC	V	06-30-19	0.017	13
1	DN	VC	V	06-30-19	0.032	12.9
1	DN	VC	V	06-30-19	0.025	12.6
2	DN	VC	A2	06-30-19	0.021	13.5
2	DN	VC	A2	06-30-19	0.022	14.1
2	DN	VC	A2	06-30-19	0.031	14.7
2	DN	VC	A2	06-30-19	0.026	10.9
2	DN	VC	A2	06-30-19	0.025	12.5
3	DN	VC	J	06-30-19	0.02	13.3
3	DN	VC	J	06-30-19	0.022	13.9
3	DN	VC	J	06-30-19	0.032	13.8
3	DN	VC	J	06-30-19	0.017	10.6
3	DN	VC	J	06-30-19	0.017	13
4	DN	VC	WoodDuck	06-30-19	0.033	11.8
4	DN	VC	WoodDuck	06-30-19	0.02	13.4
4	DN	VC	WoodDuck	06-30-19	0.026	13
4	DN	VC	WoodDuck	06-30-19	0.042	13.5
4	DN	VC	WoodDuck	06-30-19	0.016	13.3
4	DN	VC	WoodDuck	06-30-19	0.021	13.1
1	DN	NVC	A2	06-30-19	0.025	13.8
1	DN	NVC	A2	06-30-19	0.03	14.5
1	DN	NVC	A2	06-30-19	0.029	13.5
1	DN	NVC	A2	06-30-19	0.03	12.6
1	DN	NVC	A2	06-30-19	0.034	13.7
1	DN	NVC	A2	06-30-19	0.025	14.1

2	DN	NVC	J	06-30-19	0.019	14.7
2	DN	NVC	J	06-30-19	0.021	14.6
2	DN	NVC	J	06-30-19	0.025	14.5
2	DN	NVC	J	06-30-19	0.023	12.7
2	DN	NVC	J	06-30-19	0.033	12.9
2	DN	NVC	J	06-30-19	0.027	13.6
3	DN	NVC	V	06-30-19	0.017	12.8
3	DN	NVC	V	06-30-19	0.015	12.9
3	DN	NVC	V	06-30-19	0.019	13.1
3	DN	NVC	V	06-30-19	0.028	13.2
3	DN	NVC	V	06-30-19	0.036	12.5
4	DN	NVC	WoodDuck	06-30-19	0.017	13.1
4	DN	NVC	WoodDuck	06-30-19	0.019	12.8
4	DN	NVC	WoodDuck	06-30-19	0.013	10.4
4	DN	NVC	WoodDuck	06-30-19	0.015	12.3
4	DN	NVC	WoodDuck	06-30-19	0.022	13.1
4	DN	NVC	WoodDuck	06-30-19	0.02	12.4
1	DN	VNC	A2	06-30-19	0.03	12.3
1	DN	VNC	A2	06-30-19	0.032	12.1
1	DN	VNC	A2	06-30-19	0.03	11.4
1	DN	VNC	A2	06-30-19	0.022	11.9
1	DN	VNC	A2	06-30-19	0.03	13.4
1	DN	VNC	A2	06-30-19	0.033	13.5
2	DN	VNC	V	06-30-19	0.013	12.8
2	DN	VNC	V	06-30-19	0.019	11.8
2	DN	VNC	V	06-30-19	0.015	12.3
2	DN	VNC	V	06-30-19	0.017	12.5
3	DN	VNC	WoodDuck	06-30-19	0.017	13
3	DN	VNC	WoodDuck	06-30-19	0.023	10.2
3	DN	VNC	WoodDuck	06-30-19	0.019	12.4
3	DN	VNC	WoodDuck	06-30-19	0.02	12.6
3	DN	VNC	WoodDuck	06-30-19	0.013	11.8
4	DN	VNC	J	06-30-19	0.017	13.4
4	DN	VNC	J	06-30-19	0.033	11.9
4	DN	VNC	J	06-30-19	0.015	12.8
4	DN	VNC	J	06-30-19	0.024	13.2
4	DN	VNC	J	06-30-19	0.03	12.4
4	DN	VNC	J	06-30-19	0.02	12.5
1	DN	NVNC	A2	06-30-19	0.035	12.3

1	DN	NVNC	A2	06-30-19	0.022	13.3
1	DN	NVNC	A2	06-30-19	0.02	10.4
2	DN	NVNC	J	06-30-19	0.017	13.4
2	DN	NVNC	J	06-30-19	0.028	12.6
2	DN	NVNC	J	06-30-19	0.02	13.9
2	DN	NVNC	J	06-30-19	0.019	13
2	DN	NVNC	J	06-30-19	0.02	12.4
2	DN	NVNC	J	06-30-19	0.024	13
3	DN	NVNC	WoodDuck	06-30-19	0.022	12.6
3	DN	NVNC	WoodDuck	06-30-19	0.014	14.1
3	DN	NVNC	WoodDuck	06-30-19	0.02	12.8
1	DB	VC	J	07-13-19	0.022	10.5
1	DB	VC	J	07-13-19	0.015	13.2
1	DB	VC	J	07-13-19	0.022	14.8
1	DB	NVC	A2	07-13-19	0.037	11.1
1	DB	VNC	A2	07-13-19	0.01	12.1
1	DB	VNC	A2	07-13-19	0.09	8.9
1	DB	VNC	A2	07-13-19	0.015	8.4
1	DB	VNC	A2	07-13-19	0.02	14.1
2	DB	VNC	J	07-13-19	0.014	8.7
3	DB	VNC	N	07-13-19	0.014	12.2
3	DB	VNC	N	07-13-19	0.015	13.5
3	DB	VNC	N	07-13-19	0.013	13.3
3	DB	VNC	N	07-13-19	0.037	11.5
1	DB	NVNV	A2	07-13-19	0.016	11.9
2	DB	NVNV	J	07-13-19	0.019	7
2	DB	NVNV	J	07-13-19	0.014	13.1
2	DB	NVNV	J	07-13-19	0.012	12.9
2	DB	NVNV	J	07-13-19	0.021	14
2	DB	NVNV	J	07-13-19	0.015	13.1
2	DB	NVNV	J	07-13-19	0.031	14.4
2	DB	NVNV	J	07-13-19	0.013	10
3	DB	NVNV	N	07-13-19	0.012	12.5
1	DN	VC	V	07-13-19	0.019	7
1	DN	NVC	J	07-13-19	0.032	12.1
1	DN	NVC	J	07-13-19	0.014	9.5
1	DN	VNC	J	07-13-19	0.015	7.9
1	DN	NVNC	J	07-13-19	0.032	13.7
1	DN	NVNC	J	07-13-19	0.021	11.8

Table S4. Deaths documented during the experiment

<b>Treatment</b>	<b>Brood</b>	<b>Day</b>	<b># Dead Salamanders</b>	<b># Dead Diving Beetles</b>	<b># Dead Dragonfly Nymphs</b>
NVC	V	06-16-19	1	N/A	0
VNC	V	06-16-19	1	N/A	0
NVC	J	06-17-19	3	0	N/A
VNC	N	06-17-19	1	0	N/A
VC	J	06-17-19	1	N/A	0
VC	WD	06-17-19	1	N/A	0
NVC	V	06-17-19	1	N/A	0
NVNC	WD	06-17-19	2	N/A	0
NVC	J	06-18-19	3	0	N/A
VNC	V	06-18-19	1	N/A	0
NVC	WD	06-19-19	0	1	N/A
VNC	A2	06-19-19	0	1	N/A
VNC	J	06-19-19	0	1	N/A
NVC	N	06-20-19	0	1	N/A
VC	WD	06-21-19	1	0	N/A
VNC	A2	06-21-19	0	1	N/A
NVC	WD	06-21-19	0	1	N/A
VNC	N	06-22-19	0	1	N/A
VC	WD	06-23-19	0	1	N/A
VNC	WD	06-23-19	0	1	N/A
VNC	WD	06-23-19	1	N/A	0
VC	N	06-24-19	0	1	N/A
VC	J	06-24-19	0	1	N/A
VNC	A2	06-24-19	0	1	N/A
NVC	A2	06-24-19	0	1	N/A
NVNC	V	06-24-19	2	N/A	0
NVC	N	06-25-19	0	1	N/A
NVC	WD	06-25-19	0	1	N/A
NVNC	V	06-25-19	2	N/A	0
NVNC	V	06-26-19	1	N/A	0
VNC	J	06-27-19	0	1	N/A
NVNC	V	06-27-19	1	N/A	0
NVC	A2	06-27-19	1	N/A	0
NVNC	A2	06-27-19	1	N/A	0
NVC	A2	06-28-19	1	N/A	0
VNC	V	06-28-19	1	N/A	0

NVNC	A2	06-28-19	1	N/A	0
VC	WD	07-01-19	1	0	N/A
VC	N	07-01-19	1	0	N/A
VNC	WD	07-01-19	1	0	N/A
VNC	J	07-01-19	1	0	N/A
VNC	J	07-01-19	3	N/A	0
VNC	WD	07-01-19	5	N/A	0
VC	J	07-02-19	1	N/A	0
VC	A2	07-03-19	1	1	N/A
VNC	WD	07-03-19	1	0	N/A
NVC	N	07-03-19	1	0	N/A
VC	A2	07-03-19	2	N/A	0
VC	V	07-03-19	2	N/A	0
NVNC	N	07-03-19	1	0	N/A
NVC	WD	07-03-19	1	N/A	0
VNC	J	07-03-19	1	N/A	0
NVNC	WD	07-03-19	3	N/A	0
NVNC	A2	07-03-19	1	N/A	0
VC	A2	07-04-19	2	0	N/A
VC	WD	07-04-19	2	0	N/A
VNC	N	07-04-19	1	N/A	0
NVC	WD	07-04-19	2	0	N/A
VC	J	07-04-19	1	N/A	0
NVC	A2	07-04-19	1	N/A	0
NVC	WD	07-04-19	2	N/A	0
VNC	WD	07-05-19	1	0	N/A
NVC	J	07-05-19	1	N/A	0
VC	V	07-05-19	0	N/A	1
VC	A2	07-05-19	2	0	N/A
NVC	A2	07-05-19	1	0	N/A
VC	WD	07-05-19	1	N/A	0
VC	A2	07-05-19	2	N/A	0
NVNC	WD	07-05-19	1	0	N/A
VNC	V	07-05-19	1	N/A	0
NVC	WD	07-05-19	3	N/A	1
NVNC	WD	07-05-19	1	N/A	0
NVNC	J	07-05-19	1	N/A	0
NVNC	A2	07-07-19	2	0	N/A
NVNC	N	07-07-19	2	0	N/A

NVNC	WD	07-07-19	2	0	N/A
VC	WD	07-07-19	5	0	N/A
VC	A2	07-07-19	1	N/A	0
NVC	A2	07-07-19	1	N/A	0
NVC	J	07-07-19	1	N/A	0
VC	A2	07-08-19	1	0	N/A
NVC	WD	07-08-19	1	0	N/A
NVC	A2	07-08-19	2	0	N/A
VC	V	07-08-19	1	N/A	0
NVNC	WD	07-08-19	3	0	N/A
VNC	J	07-08-19	1	0	N/A
NVC	V	07-08-19	1	N/A	0
VNC	V	07-08-19	1	N/A	0
VNC	A2	07-08-19	1	N/A	0
NVNC	J	07-08-19	1	N/A	0
NVNC	WD	07-08-19	1	N/A	0
VC	J	07-09-19	1	0	N/A
VC	N	07-09-19	1	0	N/A
NVC	WD	07-09-19	1	0	N/A
NVC	A2	07-09-19	1	0	N/A
NVNC	A2	07-09-19	2	0	N/A
NVNC	N	07-09-19	1	0	N/A
VC	A2	07-09-19	1	N/A	0
NVC	V	07-09-19	2	N/A	0
VNC	V	07-09-19	2	N/A	0
VNC	A2	07-09-19	1	N/A	0
VNC	A2	07-09-19	3	N/A	0
VC	N	07-10-19	4	0	N/A
VNC	WD	07-10-19	1	0	N/A
VNC	N	07-10-19	1	0	N/A
NVC	WD	07-10-19	1	0	N/A
VNC	J	07-10-19	1	0	N/A
VC	V	07-10-19	1	N/A	0
NVC	V	07-10-19	1	N/A	0
VNC	A2	07-10-19	2	N/A	0
VC	J	07-11-19	1	0	N/A
NVC	WD	07-11-19	1	0	N/A
VNC	J	07-11-19	1	0	N/A
VC	J	07-11-19	1	N/A	0

VC	V	07-11-19	1	N/A	0
NVC	A2	07-11-19	1	N/A	0
VNC	A2	07-11-19	2	N/A	0
NVNC	J	07-11-19	1	N/A	0
VC	J	07-12-19	1	0	N/A
VNC	WD	07-12-19	1	0	N/A
NVC	A2	07-12-19	1	0	N/A
NVNC	A2	07-12-19	1	0	N/A
VC	J	07-12-19	1	N/A	0
NVC	A2	07-12-19	1	N/A	0
NVC	V	07-12-19	1	N/A	0
VC	J	07-13-19	1	0	N/A
VC	WD	07-13-19	1	0	N/A
VNC	A2	07-13-19	4	0	N/A
NVC	A2	07-13-19	1	0	N/A
VNC	J	07-13-19	1	0	N/A
VNC	N	07-13-19	1	0	N/A
NVC	J	07-13-19	2	N/A	0
VC	V	07-13-19	1	N/A	0
NVNC	J	07-13-19	1	N/A	0
VNC	J	07-13-19	1	N/A	0
NVNC	J	07-13-19	1	0	N/A

<sup>1</sup>WD stands for Wood Duck