COMPARISON OF VARIOUS POPULATION PARAMETERS FOR GREEN FROGS ACROSS THREE DIFFERENT WETLAND HABITATS AT PIERCE CEDAR CREEK INSTITUTE

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Introduction

In order to be reproductively successful, pond breeding amphibians like green frogs (*Rana clamitans*) must choose appropriate habitat in which larvae can develop and metamorphose. While this may seem like a simple task, numerous environmental pressures have been shown to have significant impacts on the growth and development of larvae. For instance, low temperature has been shown to influence feeding rate (Warkentin 1992a; Warkentin 1992b), growth and differentiation rates, size at metamorphosis (Berven et al. 1979), and predation rates (Moore and Townsend 1998).

Pond hydroperiod further confound the choice of breeding wetlands as temporary ponds may dry before larvae metamorphose resulting in high mortality (Martof 1956; Berven et al. 1979). In contrast more permanent ponds may have more abundant and diverse predator threats (Werner and McPeek 1994; Skelly 1996) which in turn has been shown to impact various parameters associated with survival including activity periods, growth rates, as well as survival (Relyea and Werner 1999; Anholt et al. 2000; Eklov and Werner 2000; Thiemann and Wassersug 2000). With the additive effect of temperature (temporary ponds are often warmer than permanent ponds), presence of vegetation, dissolved oxygen and any number of other parameters that influence larval growth and development, it is clear that selective pressures can make it difficult to be reproductively successful.

Strategies to address challenges in selecting appropriate breeding wetlands are to focus on one wetland type with its specific selective pressures. For instance, spadefoot toads are more likely to use temporary wetlands and face pressure of undergoing metamorphosis before the ephemeral pools disappears (Newman 1989; Denver et al. 1998). At the other extreme, Bullfrogs are only reproductively successful in deeper permanent ponds as their larvae often take up to 2 years to develop (Harding 1997). A second would be to show greater plasticity in larval traits associated with the range of selective pressures encountered (Van Buskirk 2002). This would allow a species to occupy a wide range of wetland habitats.

Green frogs are common and widespread species found throughout the great lakes (and much of Eastern U.S.) and are known to be habitat generalists, breeding in numerous wetland habitats (Harding 1997). This ability to occupy multiple habitats may explain their relative success in establishing and maintaining populations while other conspecific amphibian populations have shown significant declines (Lannoo 1998). Each of these various habitats has the potential to have unique selective pressures to which a specific population of green frogs must adapt (Berven et al. 1979). Selective pressures may also impact adult growth, survival, reproductive phenology, etc. (McEvoy and Durtsche 2004; Maerz et al. 2005). However, beyond Berven et al. (1979) little has been done to comparatively quantify how ecological parameters for populations of green frogs in different wetland habitats might vary.

In work done at Pierce Cedar Creek Institute (PCCI) in 2007, there was indication that the green frogs in the Hyla House Pond and a wooded pond on Yellow Trail showed differences in terms of breeding phenology (we did not hear calling occurring at all during visits to the wooded pond even though sexually mature males were present) and apparent body size (adults seemed smaller, although no quantitative measures were recorded). The two ponds are significantly different in the amount of direct sunlight, the type of aquatic litter, presence of aquatic vegetation, and incidental work suggested that dissolved oxygen levels were low at the wood pond. Further, work at a large permanent wetland at GVSU found that green frog males were considerably larger than males at the Hyla House Pond (seasonal/semi-permanent pond).

Both sets of anecdotal evidence indicate that populations of green frogs encountering different environmental characteristics may manifest different ecological traits and population characteristics.

In this project, we quantify population parameters for green frogs at PCCI across three wetlands representing different macrohabitat types. It is anticipated, then, that populations encountered in these different habitats within the same region (PCCI) should show varied responses to: 1 - Timing and length of breeding activity, 2 – ratio of males to females during breeding activity, 3 - Adult body sizes, and 4 - Larval growth and development rates.

Methods and Materials

Study Areas

This study was conducted in three separate wetlands at Pierce Cedar Creek Institute (PCCI) in Hastings, MI *(figure 1*). The three wetlands, chosen for their different habitat types and known presence of green frogs, consisted of a meadow wetland just east of the Hyla House property, a small pond lacking vegetative growth north of Blue Trail, and Brewster Lake. The Hyla House wetland is bounded by Cloverdale Road (dirt road) to the north, residential property to the west (Hyla House), and abandoned agricultural fields to the east and south. This relatively shallow wetland is seasonal; maintaining water throughout the spring and part of the summer during dry years while in wet years it may maintain water the entire year. There is no direct drainage (stream) that feeds into or out of this wetland. Hyla House Pond is unshaded with apparently high productivity (abundant aquatic vegetation), with no fish predators. The nearest wetland appears to be another seasonal wetland on private property north of Cloverdale road. The pond north of Blue Trail (referred to as Wood Pond) is surrounded on all sides by deciduous forest, lacks vegetative pond growth and solar radiation, and is a permanent to semi-permanent pond also lacking in aquatic predators and drainage. The nearest wetland is located in a ravine south of Blue Trail. Brewster Lake is a large oligotrophic lake with most of the area consisting of deep open water. The shoreline is lined with deep muck and vegetation. It is bordered almost entirely surrounded by deciduous forest and is fed and drained by Cedar Creek. This wetland has aquatic predators including largemouth bass.

We collected both water and air temperature data at these wetlands using HoboTemp Data Loggers set to record air temperature (1m shaded) and water temperature (2-3 cm below the surface) every 15 minutes. Unfortunately, the data logger at Hyla House pond stopped working a month into the study, limiting our information for this wetland.

Amphibian Sampling

To evaluate length of breeding period, we used both nighttime calling and daytime visual encounter surveys. Calling surveys were conducted at each site with calling recorded on a scale from 1 to 5. One for only a single individual heard, two for less than 5 frogs heard individually, three for more than 5 frogs calling but hard to determine individuals, four for a small chorus, unable to distinguish individuals, five for large chorus, unable to hear individuals. Daily visual surveys were done to identify egg masses with time and date eggs were located recorded. Length of breeding period would be determined by the number of days from when the first call was heard until the last egg mass was found.

Time constrained night-time searches and drift fencing/funnel traps were used to collect green frog adults and metamorphs. Night-time searches occurred every other night at each

wetland (with exception of Hyla House Pond which was surveyed 4-5 nights each week) between the hours of 21:00 and 02:00. and all individuals observed were hand-captured. Drift fences (approximately 10 meter lengths of construction fabric in the ground) were built adjacent to each of the wetlands. Two drift fences were placed on the north and south side of Wood Pond, two fences were placed on the northwest and southeast sides of Hyla House Pond), and four fences were placed on Brewster Lake (2 on the north side of the lake and 2 on the south). Pitfall traps (plastic buckets) were placed on either side of the fence at the ends and two funnel traps were placed in the middle of each drift fence array. Traps were opened each week for the length of the study period, and closed over weekends.

We weighed each captured frog in grams using spring scales, measured snout to vent length (SVL) in millimeters using calipers, and determined sex for each individual captured by secondary sex characteristics (presence of nuptial pads, tympanum:eye ratio, throat color). Frogs were considered male when tympanum diameter was larger than eye diameter and considered female when tympanum diameter was equal or less than eye diameter. Enlargement of the tympanum appears somewhat earlier than other secondary sexual characteristics and is easily measured (Martof 1956). Each individual was uniquely marked by injecting a visual implant elastomer (Northwest Marine Technology) between two toes of the front and/or hind foot. Using one to three of these marks in combination allowed us to uniquely mark each individual for recapture information. The first two phalanges of the fourth digit on the left hind foot were clipped for the potential of DNA analysis. Unmarked individuals were collected and maintained in ziplock baggies containing a small quantity of pond water labeled with their location of capture until processing. A bamboo stake was also labeled with the frog number and placed at the location of capture. After processing, we returned all frogs to the exact location of capture. The following morning each green frog location was recorded using a Global Positioning System (GPS) point for mapping purposes.

We statistically compared sizes of both males and females using a one-way ANOVA with post hoc Tukey LSD pair-wise comparisons. We used Levines Homogeneity of Variance to determine if the variable showed similar variances. All tests were conducted using SPSS 16.0.

Larval growth and development rates.

We collected green frog larvae using butterfly nets (for smaller larvae) and dip nets. We sampled for larvae in flagged locations of a few egg masses using the time the egg mass was found as an indication of tadpole age. Wood Pond was not included as no calling was ever heard. Further, no egg masses or larvae were ever found either. We sampled the same locations every two weeks and collected up to 50 larvae from each location from which weight and developmental stage were determined for each individual. These individuals were carefully transferred to a plastic tank filled with pond water and equipped with an aerator pump and taken to the wet lab for determining sizes and stages and then returned to capture location. Stages were determined from the Gosner (1960). As the larvae were often too small to weigh individually, we weighed larvae in apparently similar size groups and calculated an average stage and weight for each group. Growth was measured by the relative weight change since last sampling period. Development rates were the measure of the average change in larval stages since last sampling period.

Results

Water and Air Temperature Comparisons:

All three habitats showed similar cooling and warming trends during sampling period (*figure 2)* with air temperatures much cooler at the beginning of May and peaking around mid-June and early July. Air temperatures at Wood Pond were consistently cooler than Brewster Lake, infrequently going above 25 ºC while Brewster Lake was above 25 ºC much more often. The limited Hyla House Pond data show similar temperatures of those at Brewster Lake.

Water temperature data at all habitats are shown in *(Figure 3).* Wood Pond water temperatures were consistently cooler throughout sampling compared to Brewster Lake and Hyla House Pond *(figure 3);* rarely reaching over 20 ºC. Brewster Lake's water temperatures usually were between 20-30 ºC. Data from early may shows Hyla House Pond water temperatures were warmer than the other two wetlands. As it is shallow and relatively unshaded, we assume that water temperatures at Hyla House Pond remained higher than Brewster Lake and Wood Pond throughout the sampling period.

Sampling Effort:

Our study ranged from May 5th 2008 to June 26th 2008 at Hyla House Pond. Sampling began one week later at Wood Pond and Brewster Lake. During this allotted time we sampled 35 nights at Hyla House Pond, 14 nights at Wood Pond and 13 nights at Brewster Lake. On June 4th we were unable to sample at Brewster due to heavy rain and lightning storms. Overall we captured a total of 104 frogs at Hyla House Pond, 101 frogs at Wood Pond and 64 frogs at Brewster Lake.

Total number of frogs recaptured at Hyla House Pond was 52, Wood Pond was 63, and Brewster Lake was 15. *(Figure 4)* shows the actual percentage of males, females and juveniles that were recaptured at each location throughout the sampling period. What we found was that Wood Pond had the highest percentage of overall recaptures for males and females while Hyla House Pond shows the highest percentage of juveniles recaptured. Hyla House and Wood pond both had higher percentages of males recaptured while we recaptured females at a higher percentage at Brewster Lake.

Overall most recaptured frogs were recaptured only once at each habitat *(figure 5).* A few frogs were captured up to five times, and one frog at Hyla House Pond was recaptured up to eight different times. Wood Pond had more females recaptured multiple times compared with Hyla House Pond which had more males recaptured multiple times. Brewster Lake had fewer recaptures overall.

Population:

Jolly-Seber population estimates show considerable fluctuation over the sampling period *(figure 6).* Hyla House Pond has a larger overall estimated population size, with Wood pond showing the next largest. Only 150 meters of shoreline were sampled in Brewster Lake, so population estimates are likely underestimating the actual population size. Patterns in population estimates also appear to show an influx of individuals at each location in mid-May followed by an outflow in mid-June. Wood Pond is an exception with a third peak in late June.

Over the course of the sampling period, frogs were found throughout Hyla House Pond and along Wood Pond shoreline *(Figure 7).* Unfortunately, the high canopy cover of Wood Pond appears to have produced significant error in the GPS coordinates showing a distribution

that was much more widespread across the pond than actually found. Brewster Lake was sampled along four transects measuring 50 meters long. The highest concentration of frogs were found on the northwest transect.

Gender ratios show that Hyla House Pond had considerably greater number of males compared to females with the exception of week 3 *(figure 8)*. In contrast Wood Pond always had a greater number of females than males with the exception of week 6. Brewster Lake gender ratios fluctuated with males more common in weeks 2 and 8 and females more common in weeks 4-6.

Breeding Activity:

Calling had already started at Hyla House Pond and Brewster Lake when our project was initiated (May 2). We never heard calling at Wood Pond throughout the sampling period. Both Hyla House Pond and Brewster Lake show similar patterns in calling with low calling indices early in the sampling period and increasing to peak early June *(figure 9)*. Calling at Hyla House Pond always had a greater intensity than did Brewster Lake. Further, the first egg mass at Hyla House Pond was encountered about 2 weeks before the first egg mass at Brewster Lake *(figure 9)*.

Sizes/Growth Rates:

Size data show a strong relationship between weight and snout vent-length of all Green Frogs caught at each wetland (*figure 10)*. For individuals captured multiple times we only used the initial weight. Our graphs indicate that Hyla House Pond has larger/longer frogs than Wood Pond and Brewster Lake which are relatively similar in size. Hyla House Pond also shows a wider spectrum of male sizes compared to females; however females were relatively larger than males, while Wood Pond and Brewster Lake shows similar sizes among males and females.

There is a statistical difference for both weight and SVL for males from the different habitats (F test $p<0.005$). The post hoc comparisons show that Hyla House Pond has significantly heavier (x=37.31, std=10.45, se=0.84) and longer (x=77.04, std=6.71, se=0.54) males compared to Brewster Lake (wt x=24.58, std=9.91, se=1.87; svl x=64.33, std=8.04, se=1.52) and Wood Pond (wt x=27.53, std=9.99, se=1.87; svl x=66.90, std=8.01, se=1.54) - ($p<0.005$ for both – using Tukey's HSD).

Data for both weight and SVL of females failed the Levene homogeneity of variance test so the following should be interpreted tentatively. There is a statistical difference of both weight and SVL for females from the different ponds (F test $p<0.005$; Wt $p=0.024$, SVL $p=0.050$). The post hoc comparisons show that Hyla House Pond females were significantly heavier (x=45.65, std=10.59, se=1.74) and longer (x=80.70, std=6.10, se=1.00) compared to Brewster Lake (wt x=23.25, std=9.49, se=2.17; svl x=64.07, std=6.91, se=1.00) and Wood Pond (wt x=29.94, std=14.03, se=2.00; svl x=67.19, std=8.53, se=1.21) - ($p<0.005$ for both - using Tukey's HSD).

The average weights of new male and female frogs caught each week are shown in *(figure 11)* at all habitats. No new male frogs were caught in week three at Wood Pond. Our lines show that males at Wood and Hyla House Pond started out heavier in the first two weeks and slowly decreased in size. Brewster Lake males started small and gradually increased through weeks 3-6 before reaching similar weights of the other habitats by the end of our sampling.

Female sizes at Hyla House and Wood Pond were large on the onset while no females were caught at Brewster until week 3. Wood Pond sizes peaked at week 3 and then decreased

greatly in size. Females at Hyla House Pond stayed relatively the same size throughout sampling while Brewster Lake sizes increased slowly in later weeks.

The frogs that were recaptured were not included in average weights but their weights were still recorded to determine the average size of the frogs staying in the area throughout sampling *(figure 12)*. No male recaptures were caught week 5 at Wood Pond, and no female recaptures were caught week 7 at Hyla House Pond. Male recapture sizes were the largest at Hyla House Pond, and began to decrease slowly after week 3. At Wood Pond, recapture size of males peaked week 2 and decreased slowly and no recaptures were caught at Brewster Lake until week 4 with sizes increasing dramatically.

Female recapture sizes were similar at Hyla House and Wood Pond at Week 1 then Wood Pond decreased and leveled off around week 5 while Hyla House Pond peaked week 3 and then leveled off around week 4. Brewster Lake did not have any female recaptures until week 4 and then remained about the same.

We examined weekly weight changes by comparing individuals that were captured at least one week apart. This limited calculations to less than 5 individuals for most wetlands *(table 1)* with the exceptions of 13 males for Hyla House Pond and 22 females for Wood Pond. We standardized the changes by calculating a weekly growth rate for weight. Wood Pond had the highest weekly growth rate (1.29 g) compared to Brewster Lake (0.5 g) and Hyla House Pond (0.12). In contrast, Hyla House pond had the greatest weekly growth rate for females (2.13 g) compared to Brewster Lake (1.25 g) and Wood Pond (0.72 g). Juvenile growth rate was limited in sample size and therefore, little conclusions can be made.

Larval development over the 6 week sampling period *(table 2)* showed a greater increase in stages for Hyla House Pond (4.25 stages) compared to Brewster Lake (0.67 stages). The same pattern of increase was apparent for weight changes as well *(table 2)*, with Hyla House Pond showing the greatest increase. However, a comparison among 6-week old larvae show that Brewster Lake were 1 stage later on average and slightly larger (0.01g) than Hyla House Pond.

Discussion/Conclusion:

Population:

Population estimates show an expected pattern of increase in numbers through the peak breeding period (late May) and decreasing until the end of the sampling period *(figure 6)*. We are cautious in interpreting these results, however, as the number of individuals captured at any one sampling period were relatively low. However, increases in calling indices (another relative measure of population) also seem to show the same pattern of peaking in late May *(figure 9)*.

The fluctuations in population estimates during the peak breeding period are likely a result of varying capture rates. We don't believe the sampling effort or visibility changed during this time, however, air temperatures appear to be lower when population estimated are also lower. As ectothermic organisms, these frogs may be moving to more insulated locations (in deep grass or thick emergent vegetation) or moving sub-surface during these periods making them more difficult to find. Thus, our population estimates may show an actual trend of individuals moving habitats in response to temperature.

Breeding Activity:

Unfortunately, calling had already started at Hyla House Pond and Brewster Lake when we initiated our project, limiting our ability to determine the length of calling. However, calling had all but ceased at Hyla House Pond by the time we began sampling for larvae. In contrast, green frogs were still calling at Brewster Lake at the same time suggesting that breeding may occur over a longer period compared to Hyla House Pond.

Interestingly, we never heard breeding calls at Wood Pond throughout the sampling period. Yet, the numbers of adult males and females present (*figure 8)* would indicate that some environmental factor prevented breeding during our sampling period. According to our data (*Figure 3*), Wood pond water temperatures started much colder than Brewster Lake and Hyla House Pond and rarely reached over 20°C. Brewster Lake's water temperatures were normally between 20-30 ºC. Hyla House Pond started above 20 ºC and no data was recorded in later weeks, but it is assumed that temperatures were similar or higher than Brewster Lake. Wood Pond's low water temperatures may have been why no calling was heard. According to Wright (1914) Green Frogs don't normally commence breeding until the average pond temperature is 25 ºC (from Berven et al.1979). Those green frogs preparing to breed may have left Wood Pond due to the low water temperatures and traveled to nearby wetlands with a better suited habitat for mating. Alternatively, this pond may serve as primarily a foraging area. It is possible that water temperatures were higher after our sampling period ended, however, this wetland is semipermanent and would not have been able to sustain larvae long enough to allow them to metamorphose if breeding did occur.

With the overall pond less than 1 meter in depth, the water temperatures at Hyla House Pond are likely to have increase more quickly than those in Brewster Lake. In contrast, Brewster Lake temperatures would potentially be mediated by such a large body of water. If water temperature were influencing calling, it would help explain the greater increase in calling and higher call indices at Hyla House Pond calling compared to Brewster Lake *(figure 9)*.

Another interesting pattern noticed was that egg masses were only found after the numbers of males were at least twice the number of females (something that never happened at Wood Pond). Perhaps a critical mass of males calling is required to initiate a female's search for males with which to mate.

Sizes/Growth Rates:

Green Frogs at Hyla House Pond show higher overall average weights and SVL compared to Wood Pond and Brewster Lake which are relatively similar in sizes. In *Figure 8* the regression equation for all study areas and gender are very similar suggesting that all individuals are growing heavier and longer at similar rates. However, individuals at Hyla House Pond were significantly larger than those in the other wetlands. This could suggest that these individuals are older or just grow symmetrically at a faster rate.

Low water temperatures have been shown to influence feeding rate (Warkentin 1992a; Warkentin 1992b), growth and differentiation rates, size at metamorphosis (Berven et al. 1979), and predation rates (Moore and Townsend 1998). Larger sizes of Hyla House Pond frogs might be related to warmer water temperatures in comparison with Wood Pond and Brewster Lake's. While the water temperature data is limited for comparison, shallow ponds like Hyla House Pond often have warmer temperatures than do permanent ponds/lakes.

Hyla House Pond is a temporary pond that usually dries up at the end of summer, preventing Green Frog larvae to successfully over-winter as larvae. This may explain why so few small metamorphs were captured and why the average sizes were much larger. Our results

suggest that large adult frogs at Hyla House Pond likely traveled from overwintering and foraging locations in late May.

In contrast, Brewster Lake's larvae may over-winter as larvae, metamorphosing in early spring as water temperatures warm. According to Martof (1953), Brewster Lake's small sizes at the beginning of May, may have been due to the high numbers of new metamorphs arising. This is supported by the number of small Green Frogs captured and smaller estimated population size. However later in the season, the over-wintering tadpoles had finished developing and left the area, resulting in large breeding adults remaining for reproduction. Average sizes of green frogs at Brewster Lake increased dramatically in the last few weeks, and the average size of recaptures also increased (*figure 11 &12*). Indicating that small metamorphs were no longer being recaptured and larger frogs were sticking around or coming from somewhere else.

Unfortunately, small sample sizes limited in what we can say with regards to growth of adults and juveniles. Further, we are unable to find comparable aged larvae with which to make comparisons about growth and development. In the future, enclosures might prove useful in maintain individuals within each habitat, allowing for a more accurate and comparable measurements.

Overall, the different habitats showed differences among population parameters that appear to be attributable primarily to temperature related differences in the three wetlands. Further, some of these differences such as gender ratios may influence other parameters (timing of egg laying). We are cautious in generalizing these differences for more than one season, as seasonal differences in weather may result in alternative differences. However, if temperature (both water and air) are correlated, samples taken over multiple seasons should continue to show temperature related trends.

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Table 1: Weekly weight increase (in grams) for males, females, and juveniles in different habitats. Calculations were done by subtracting the initial weight by the final capture weight. Only individuals caught at least one week apart were used in calculating weekly growth rates. With the exception of females captured at Wood Pond and males captured at Hyla House Pond sample sizes of recaptures at least one week apart were limited. Weight change varied across habitats and across gender. Males show the greatest increase in growth at Wood Pond while females show the greatest growth at Hyla House Pond. Samples of juveniles were very limited but suggest that individuals were losing weight at Brewster Lake while gaining weight at Wood Pond. No juveniles were recaptured at Hyla House Pond more than one week apart.

	Average Weekly Growth Rate (g)		
	Brewster Lake	**Wood Pond**	**Hyla House Pond**
Male	**0.50 (n=3)**	**1.29 (n=4)**	**0.12 (n=13)**
Females	**1.25 (n=4)**	**0.72 (n=22)**	**2.13 (n=3)**
Juveniles	**-1.03 (n=2)**	**0.65 (n=1)**	**N/A**

Table 2: Estimated developmental stages (Gosner 1960) and changes of larvae at Brewster Lake and Hyla House Pond. Estimated age of larvae were determined by the earliest egg mass found in the sampling locations. Hyla House Pond larvae were approximately 4 weeks older than Brewster Lake larvae. As expected, larvae at Hyla House Pond are, on average, at later stages of development than Brewster Lake larvae. A tentative comparison of the larvae at similar ages (6 weeks) suggests that larvae are slightly more advanced at Brewster Lake. The greatest stage change occurred at Hyla House between 8 to10 weeks.

	Total Sampled	Estimated Age	Average Stage	STD	STE	Change
	29	2 weeks	24.88	0.03	0.02	
Brewster	52	4 weeks	25.29	1.30	0.39	0.41
	53	6 weeks	25.96	0.54	0.16	0.67
	50	6 weeks	24.93	0.11	0.03	
Hyla	55	8 Weeks	25.44	0.59	0.18	0.51
	90	10 Weeks	29.18	2.50	0.59	4.25

Table 3: Estimated weight and weight changes of larvae at Brewster Lake and Hyla House Pond. Estimated age of larvae were determined by the earliest egg mass found in the sampling locations. Hyla House Pond larvae were approximately 4 weeks older than Brewster Lake larvae. As expected, larvae at Hyla House Pond are, on average, heavier that Brewster Lake larvae. A tentative comparison of the larvae at similar ages (6 weeks) suggests that larvae weigh slightly more at Brewster Lake. The greatest change in stage change occurred at Hyla House between 8 to10 weeks.

	Total Sampled	Estimated Age	Average Weight (g)/Tad	STD	STE	Change
	29	2 weeks	0.03	0.00	0.00	
Brewster	52	4 weeks	0.12	0.17	0.05	0.09
	53	6 weeks	0.18	0.03	0.01	0.06
	50	6 weeks	0.17	0.07	0.02	
Hyla	55	8 Weeks	0.19	0.13	0.04	0.02
	90	10 Weeks	0.69	0.52	0.12	0.51

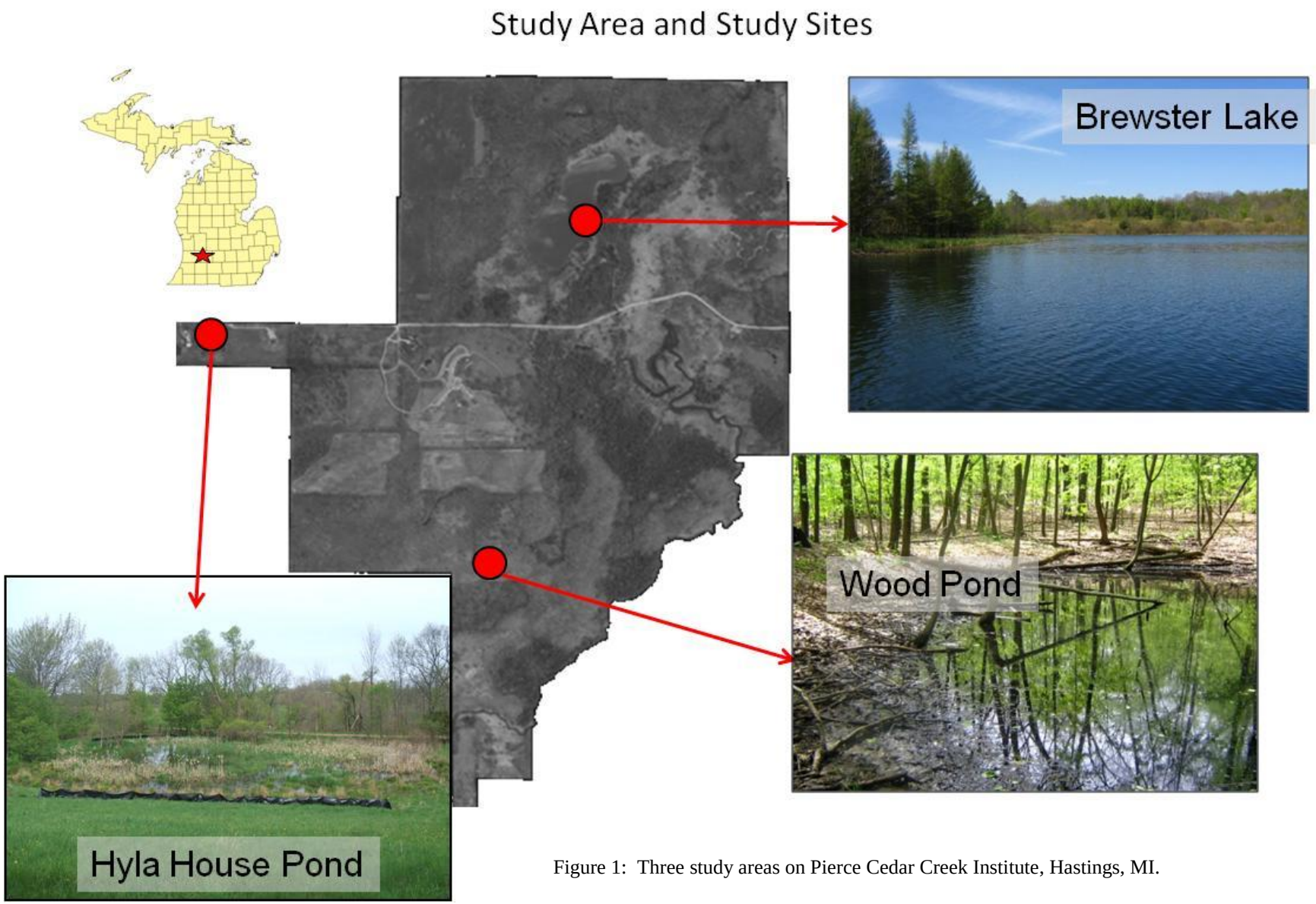

Figure 1: Three study areas on Pierce Cedar Creek Institute, Hastings, MI.

Air Temperatures

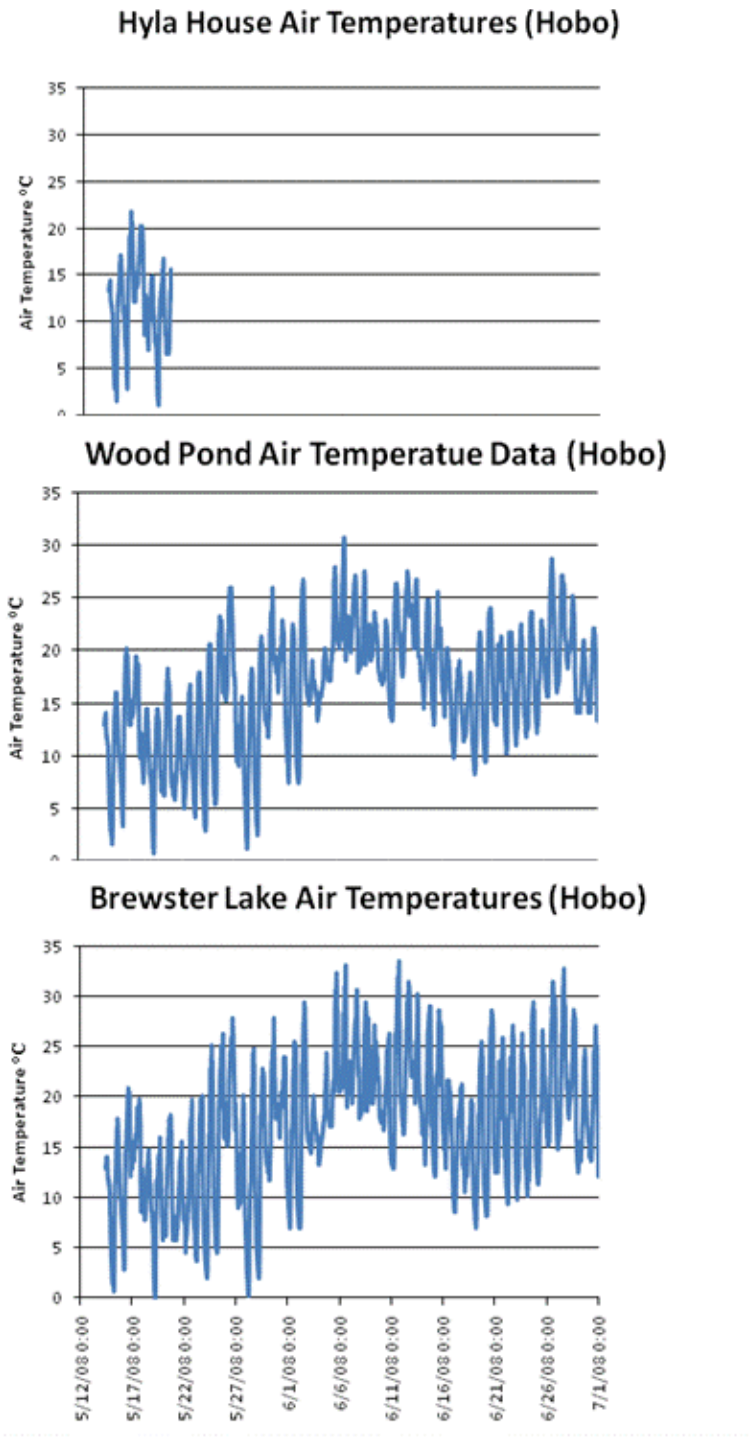

Figure 2: A comparison in air temperatures of the three sampling habitats. The temperature readings were recorded using a Hobo Temp monitoring system (probe was at 1m height and shaded). Both Brewster Lake and Wood Pond show a similar temperature pattern, with the temperatures at Wood Pond relatively cooler. Wood Pond air temperatures rarely exceeded 25^{o}C over the sampling period. Brewster Lake temperatures exceeded 25^{o}C much more frequently beginning at the end of June. The Hyla House Pond Hobo Temp only recorded temperatures for a short period, but the pattern follows that of Brewster Lake and Wood Pond during the early part of the sampling period.

Water Temperatures

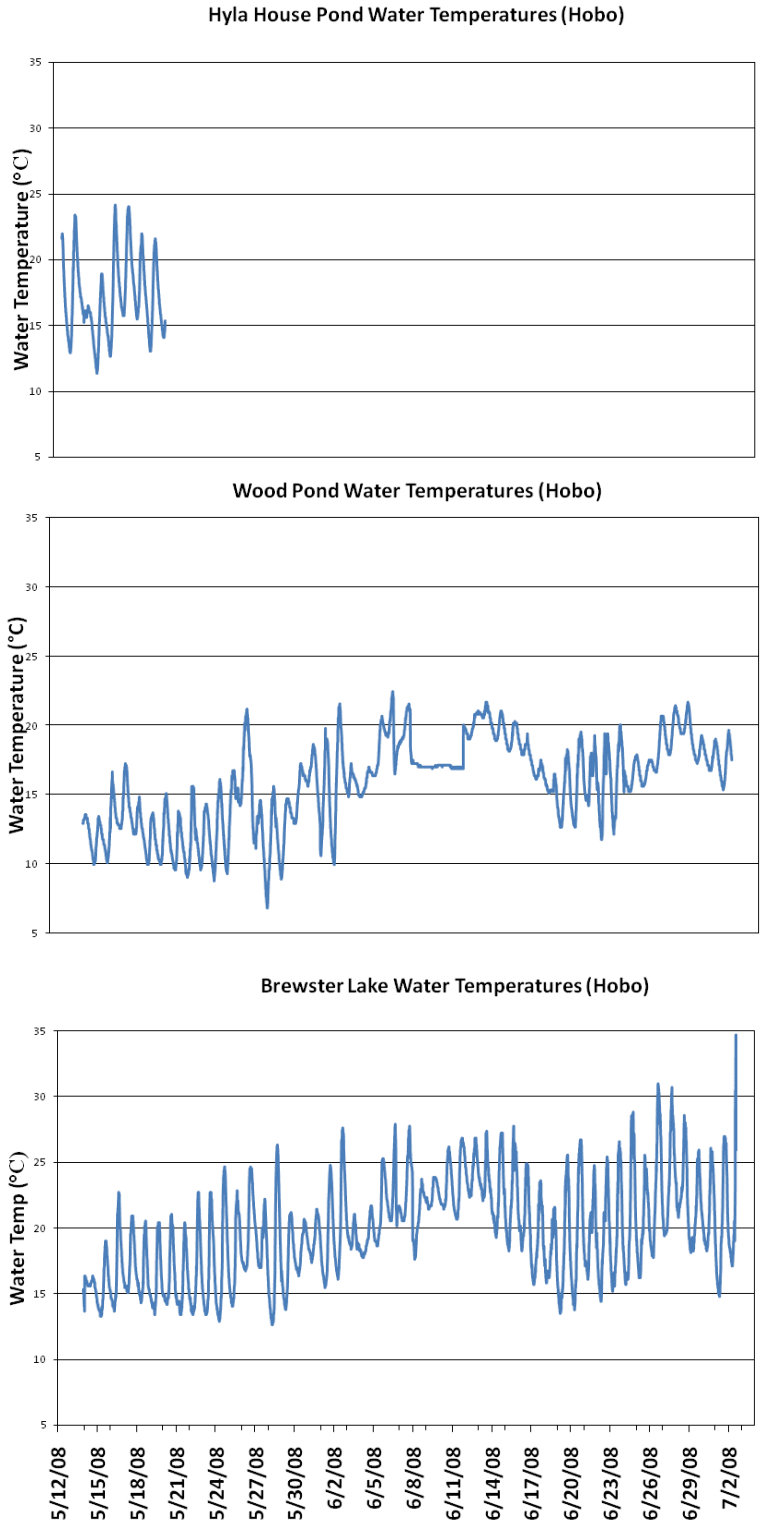

Figure 3: A comparison in water temperatures of the three sampling habitats. The temperature readings were recorded using a Hobo Temp monitoring system. Both Brewster Lake and Wood Pond show a similar temperature pattern, with the temperatures at Wood Pond much cooler overall. Wood Pond water temperatures rarely exceeded 20^{o}C over the sampling period. While Brewster Lake temperatures exceeded 25oC much more frequently beginning at the end of June. The Hyla House Pond Hobo Temp was damaged and only recorded temperatures for a short period, but the pattern follows that of Brewster Lake and Wood Pond.

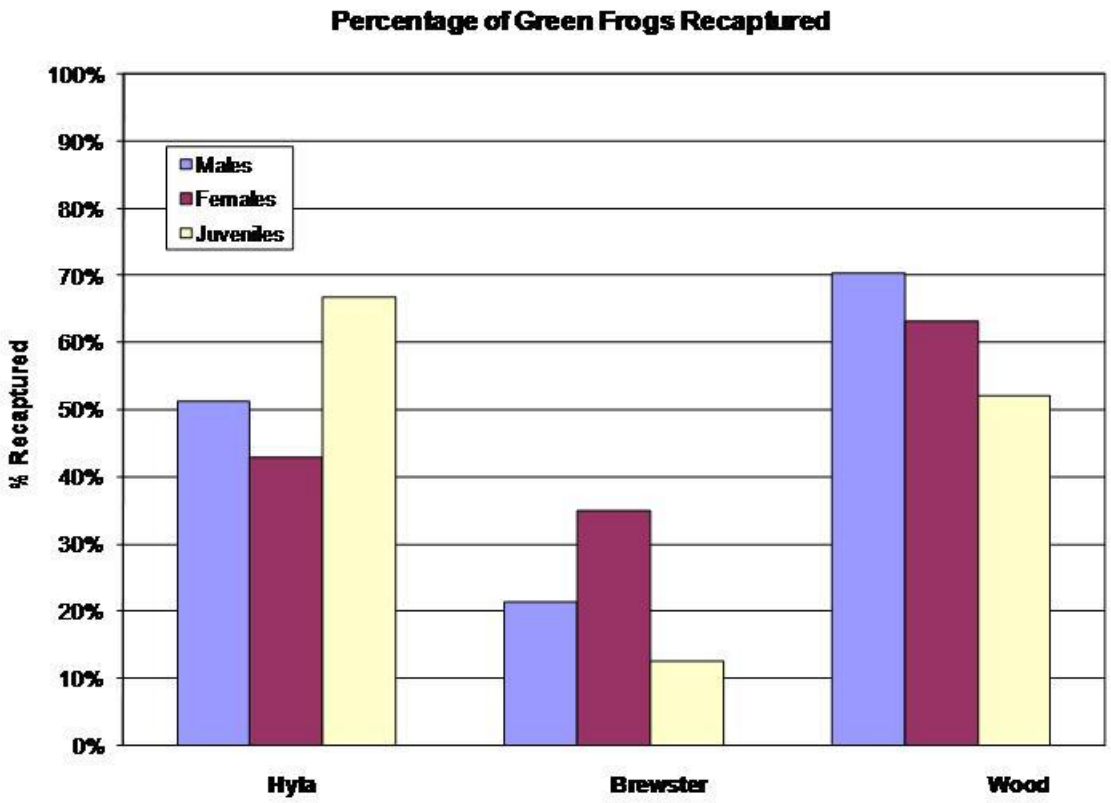

Figure 4: Recapture rates at each study location. Recapture rates were calculated by dividing the total number of individuals recaptured in a particular group (males, females, juveniles) by the total number of individuals in that group. Brewster Lake had the lowest number of recaptures compared to the other sites. Recapture rates for males and females were highest in Wood pond. Hyla House pond showed the greatest recapture rate for juveniles; however, only 3 juveniles were ever captured. Males were consistently recaptured at a greater rate compared to females except at Brewster Lake.

Frogs Recaptured More Than Once

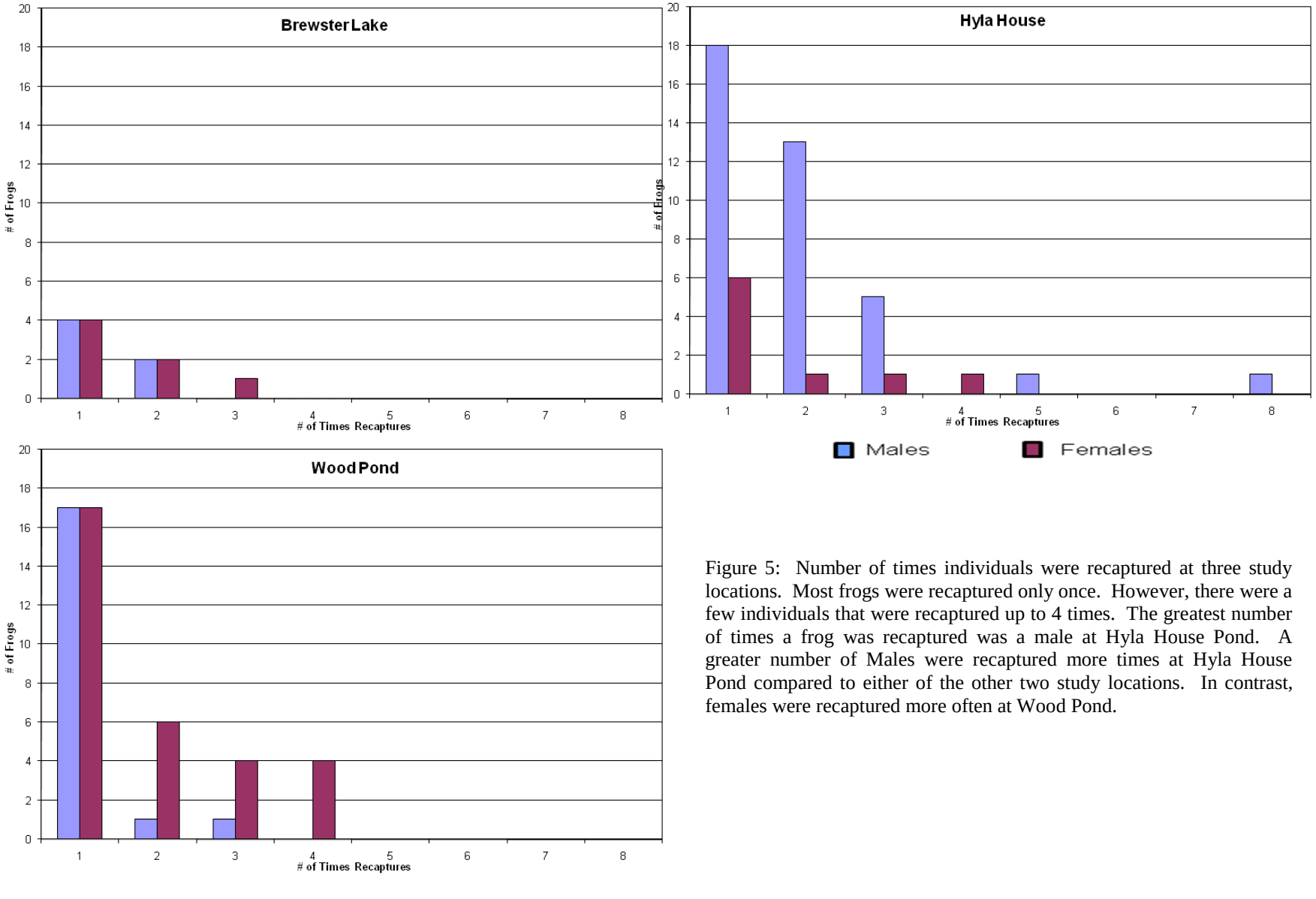

Figure 5: Number of times individuals were recaptured at three study locations. Most frogs were recaptured only once. However, there were a few individuals that were recaptured up to 4 times. The greatest number of times a frog was recaptured was a male at Hyla House Pond. A greater number of Males were recaptured more times at Hyla House Pond compared to either of the other two study locations. In contrast, females were recaptured more often at Wood Pond.

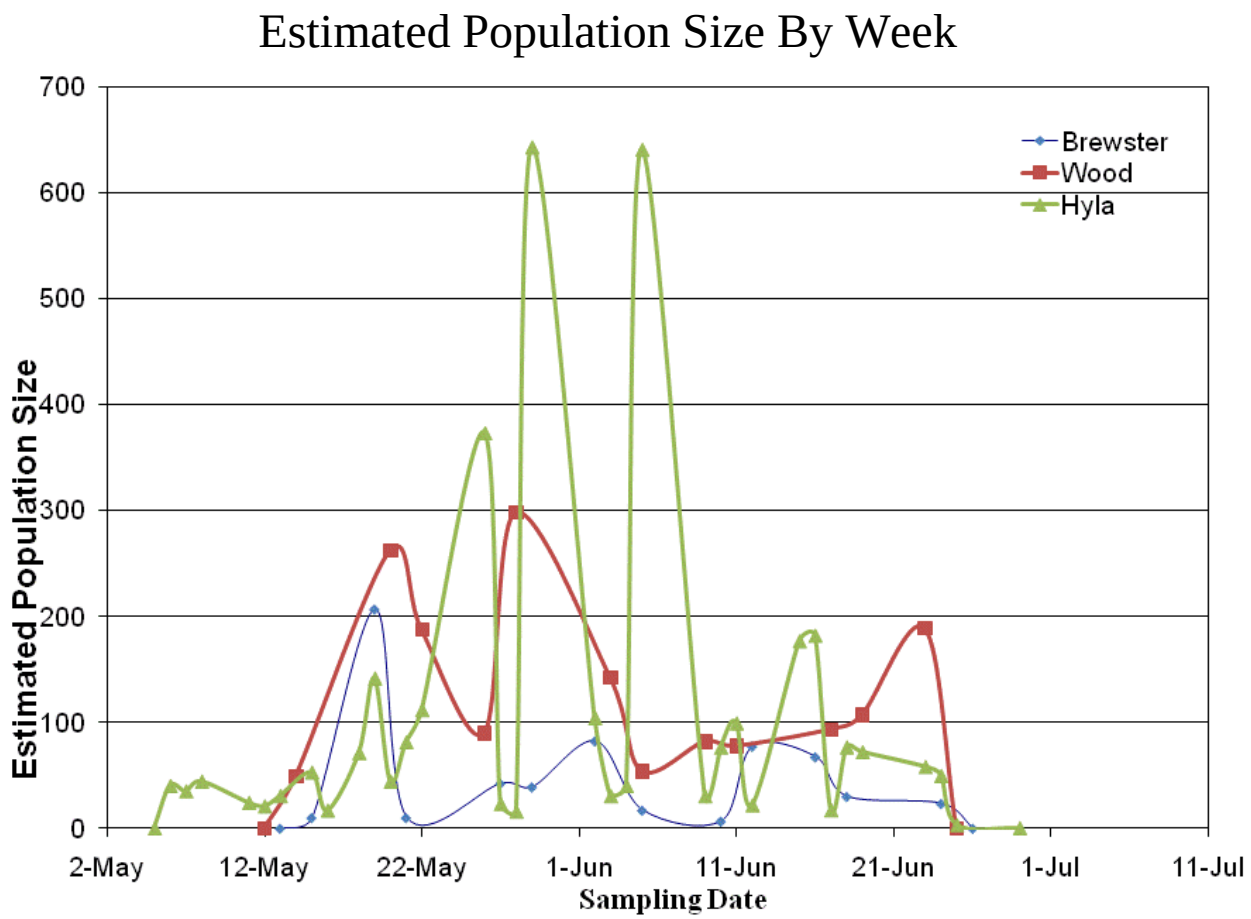

Figure 6: Jolly-Seber population estimates. Estimates were calculated with each sampling period. Hyla House Pond has a larger overall estimated population size, with Wood Pond showing the next largest. Only 150 meters of shoreline were sampled in Brewster, so population estimates are likely underestimating the actual population size. Patterns in population estimates also appear to show an influx of individuals at each location in mid-May followed by an outflow in mid-June. Wood Pond is an exception with a third peak in late June.

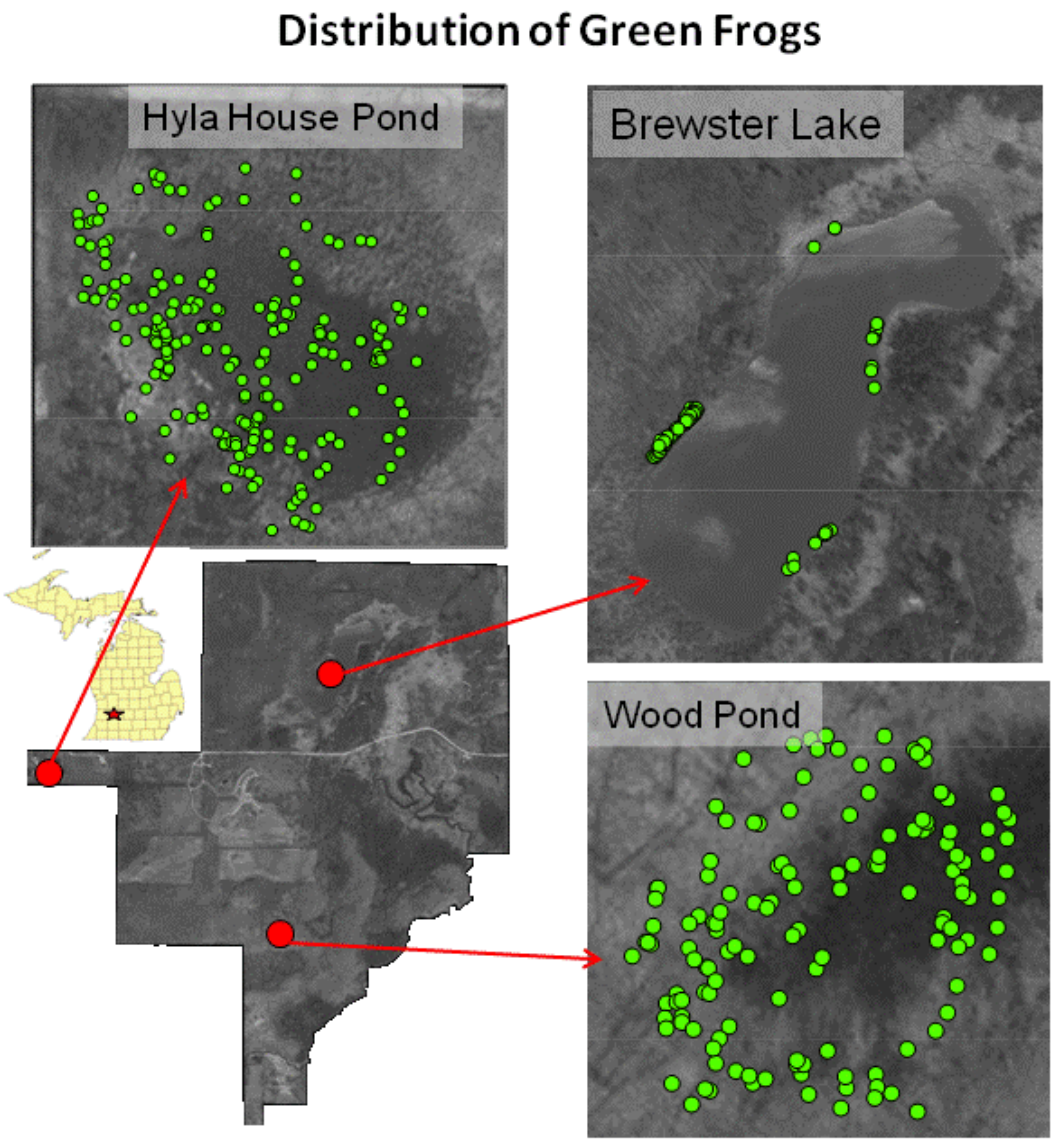

Figure 7: Distribution of frogs across sampling areas on Pierce Cedar Creek Institute, Hastings, MI. Sampling at Brewster Lake was limited to four transects measuring 50 meters in length located on opposite sides of the lake.

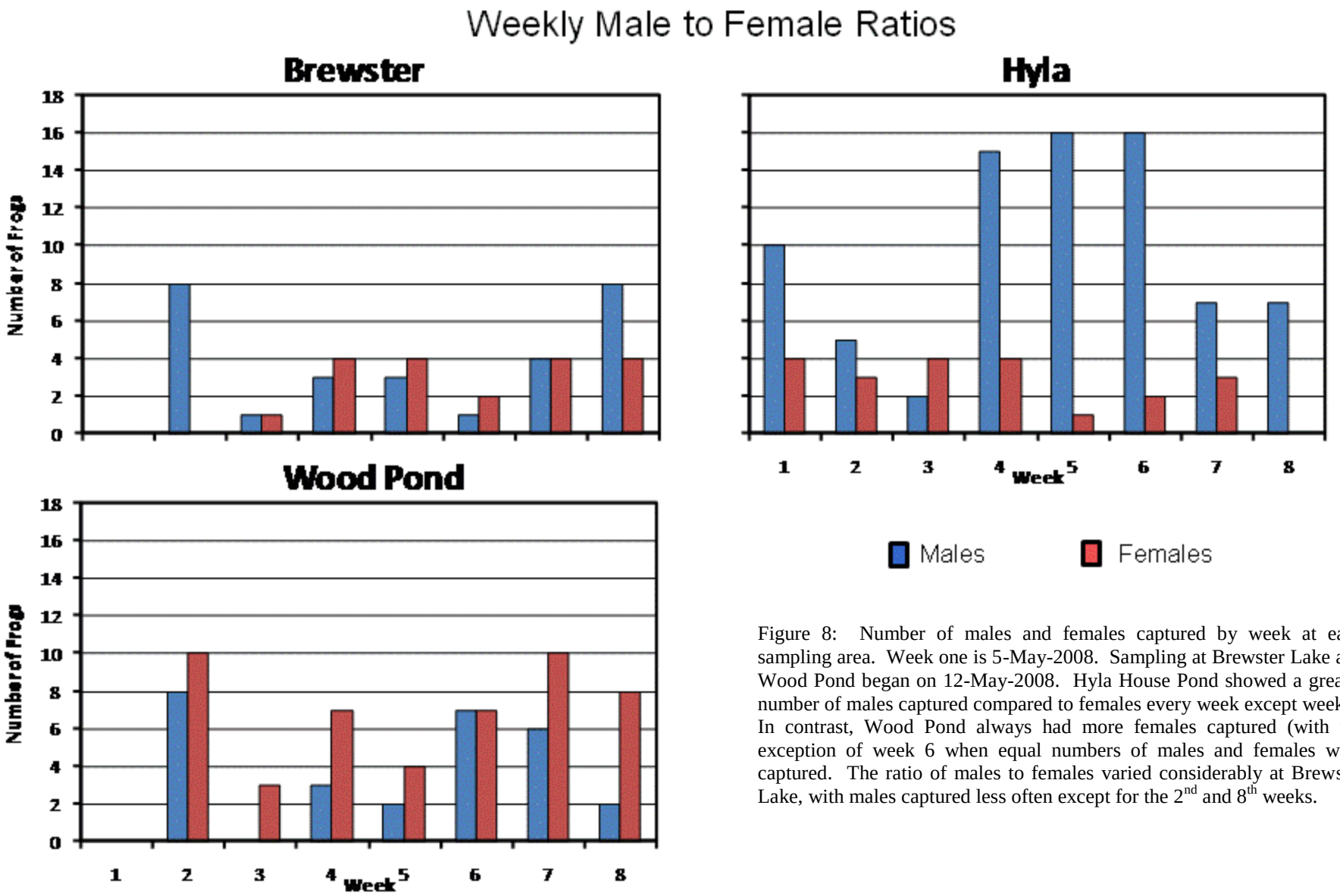

Figure 8: Number of males and females captured by week at each sampling area. Week one is 5-May-2008. Sampling at Brewster Lake and Wood Pond began on 12-May-2008. Hyla House Pond showed a greater number of males captured compared to females every week except week 3. In contrast, Wood Pond always had more females captured (with the exception of week 6 when equal numbers of males and females were captured. The ratio of males to females varied considerably at Brewster Lake, with males captured less often except for the 2nd and 8th weeks.

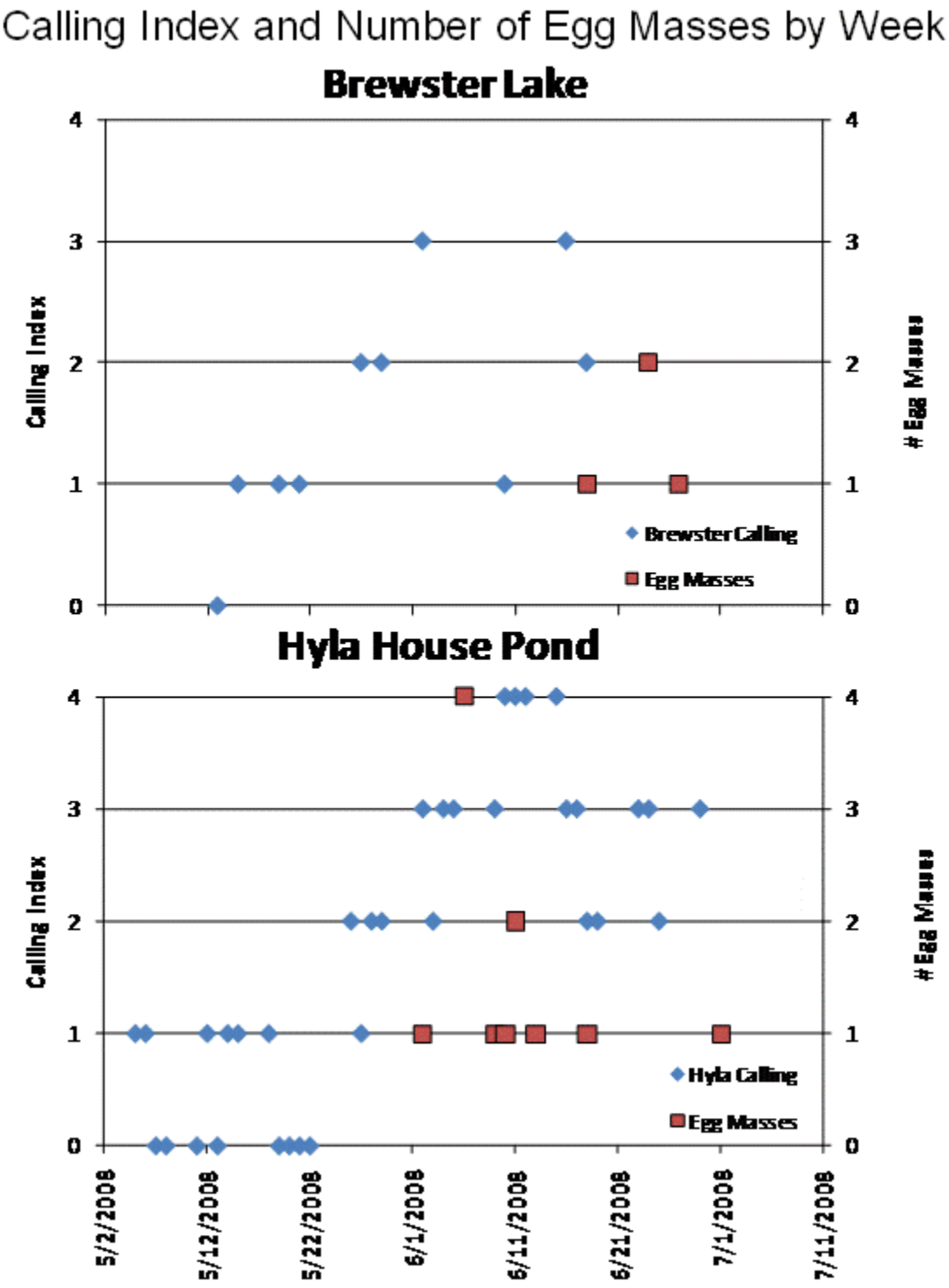

Figure 9: Calling index and number of egg masses by week. Calling indices represent an increase in the amount of calling that was heard during call surveys. Calling had already started in a limited way before the study began. However no egg masses were found in early surveys. Calling was lower at Brewster Lake compared to Hyla House Pond. First egg masses at Hyla House Pond were found almost months before egg masses were found at Brewster Lake.

Weight/Snout-Vent-Length Ratio of Males, Females and Juveniles

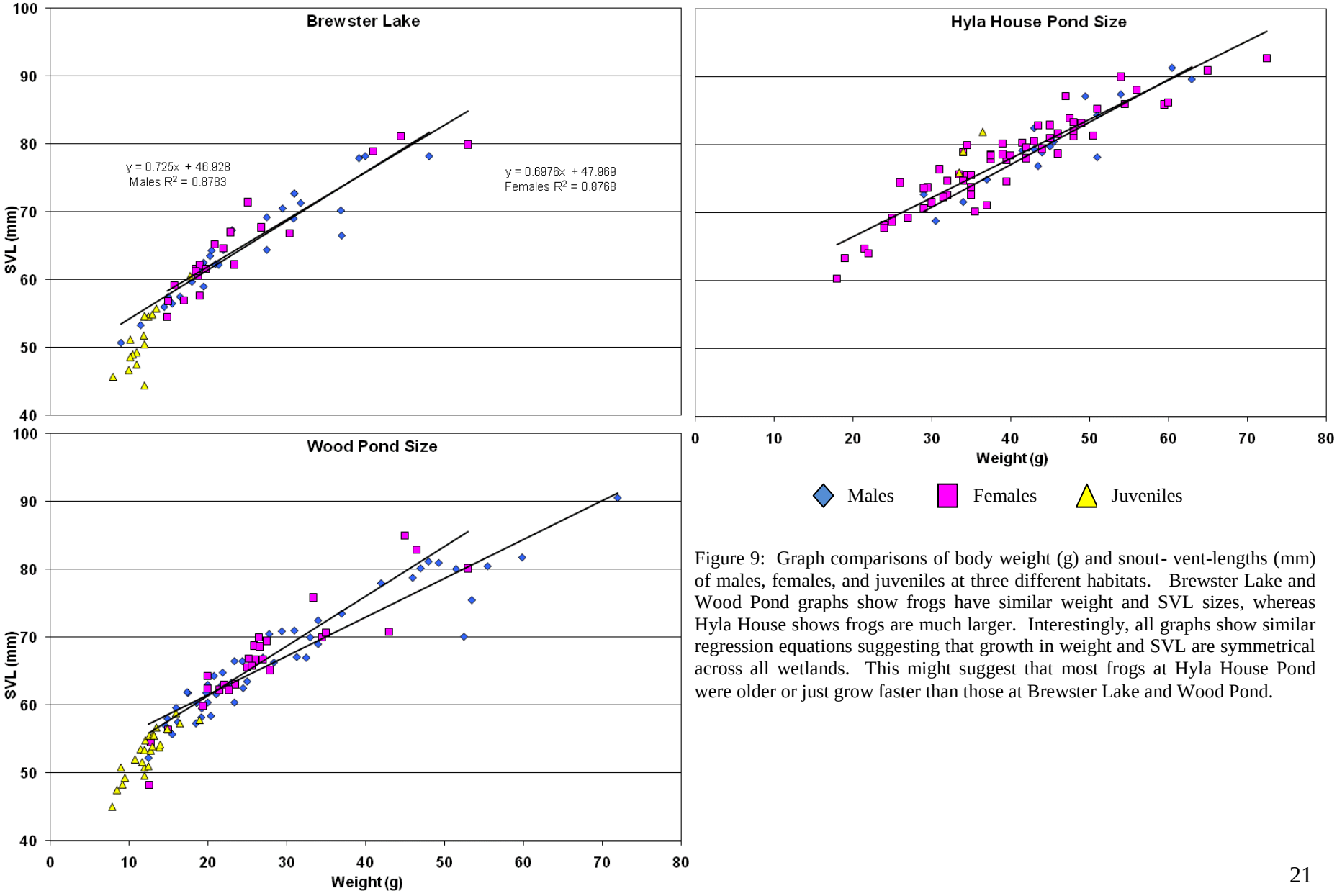

Figure 9: Graph comparisons of body weight (g) and snout- vent-lengths (mm) of males, females, and juveniles at three different habitats. Brewster Lake and Wood Pond graphs show frogs have similar weight and SVL sizes, whereas Hyla House shows frogs are much larger. Interestingly, all graphs show similar regression equations suggesting that growth in weight and SVL are symmetrical across all wetlands. This might suggest that most frogs at Hyla House Pond were older or just grow faster than those at Brewster Lake and Wood Pond.

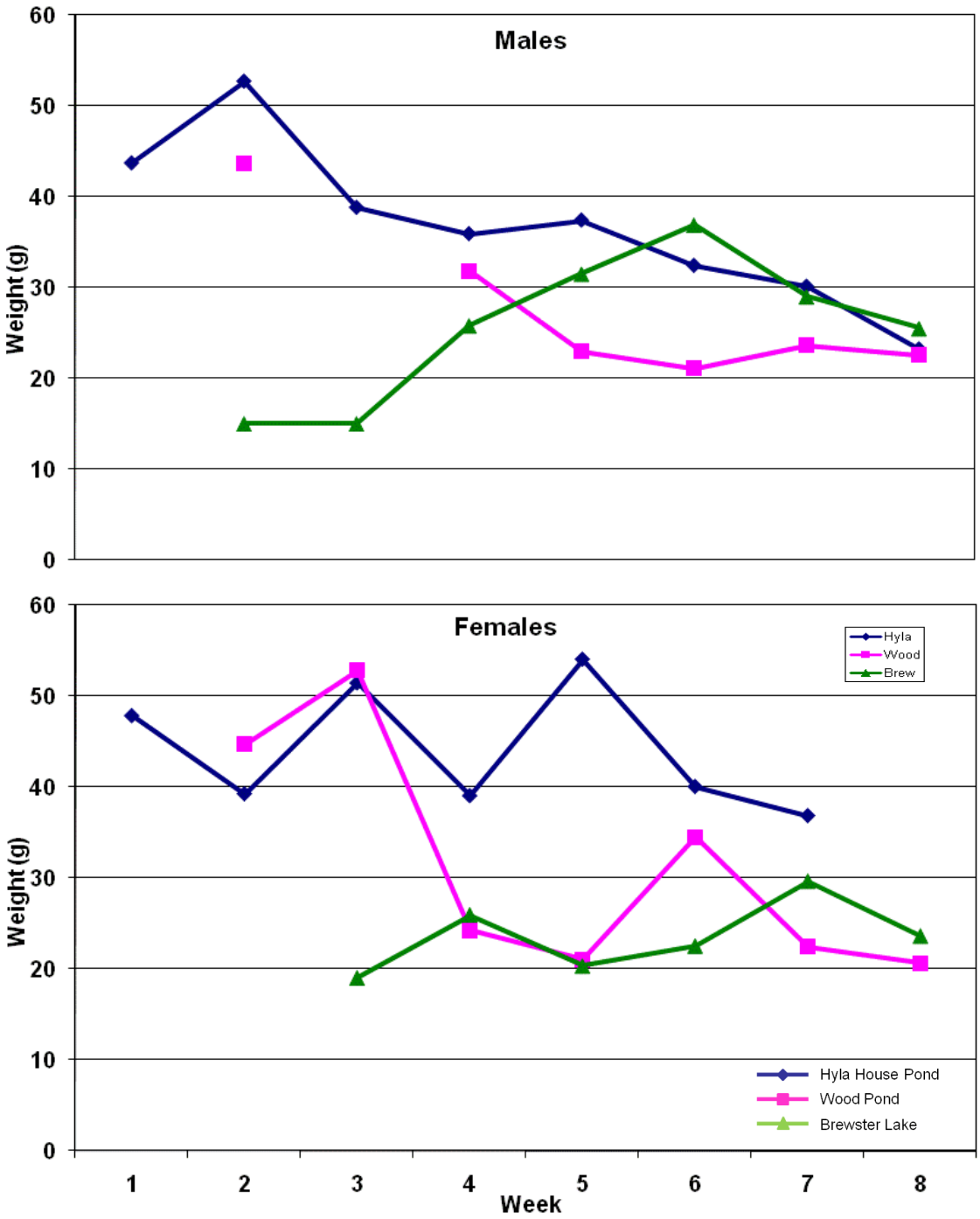

Figure 11: Average weight of males and females for each of the different habitats. Sampling occurred one week earlier at Hyla House. Data do not include recaptured individuals. Week one is 5-May-2008. No new males were captured at Wood Pond in the third week of sampling. No females were captured until the second week of sampling at Brewster Lake. New males at Hyla House and Wood Pond progressively got smaller over the sampling period, while males at Brewster Lake appear to increase (peaking around week 6) before decreasing. Females appear to remain about the same size for Brewster Lake and Hyla House Pond, While Wood Pond shows an initial decrease in female size before stabilizing.

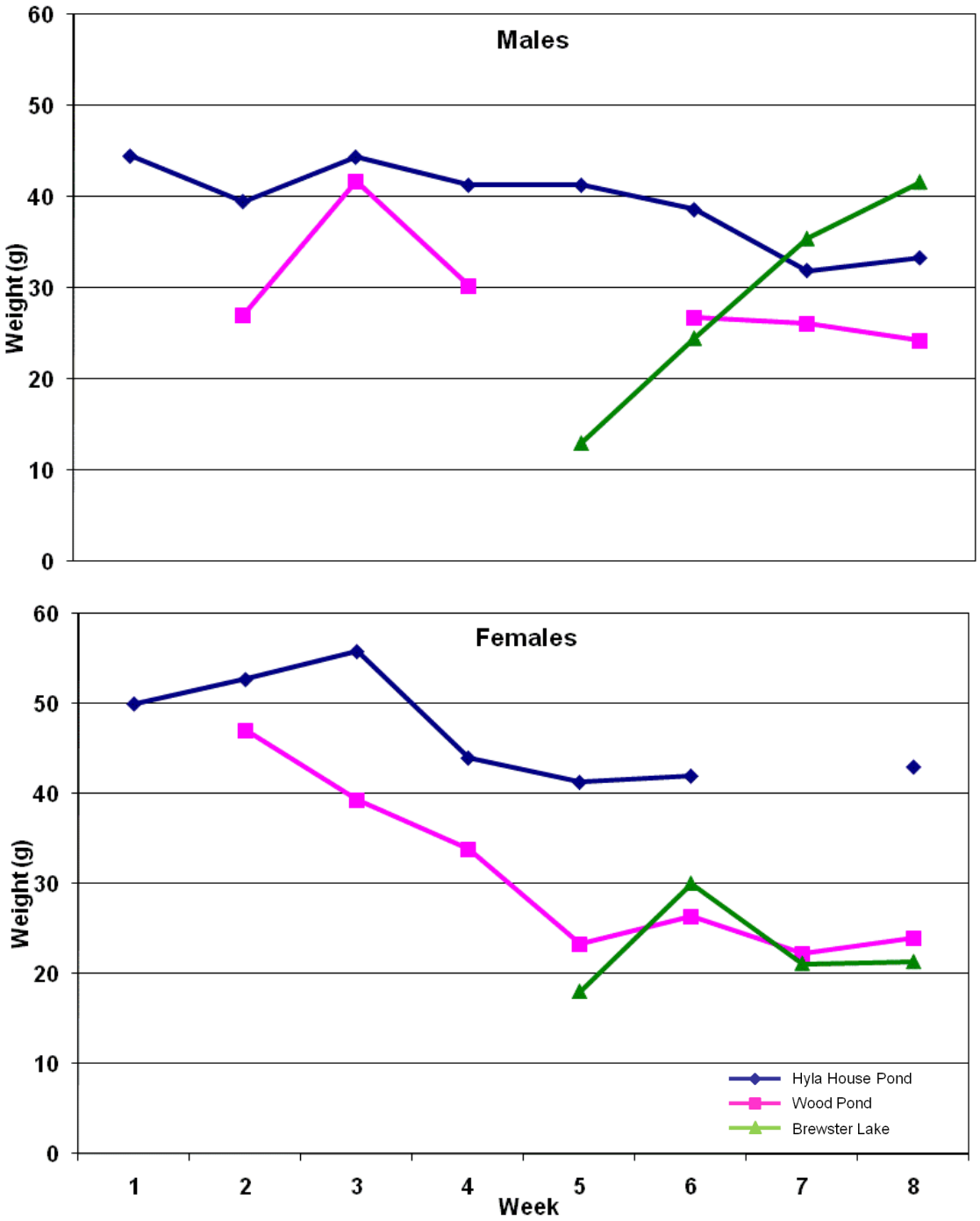

Figure 12 : Average weight of recaptured of males and females for each of the different habitats. Sampling occurred one week earlier at Hyla House. Data do not include newly captured individuals. Week one is 5-May-2008. No males were recaptured at Wood Pond in the fifth week of sampling or weeks 2 -4 for Brewster Lake. No females were captured until the fifth week of sampling at Brewster Lake. No females were recaptured at Hyla House Pond during week seven. It appears that recaptured males were progressively larger at Brewster Lake, while weights of recapture males were relatively stable at Wood and Hyla House Pond . Sizes of females at Wood Pond appear to be decreasing until the 4th week of sampling while recaptured females at Brewster Lake and Hyla House Pond remain relatively similar.