Tracking the Phenology of Egg Laying by Spotted Salamanders

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*Ephemeral ponds serve as predator-free habitats for larvae of several amphibian species that would otherwise be consumed by fish. These temporary pools also contain a variety of crustaceans that provide food for growing salamander larvae. Adult spotted salamanders (*Abystoma maculatum*) live underground, but undergo mass migrations to ephemeral ponds to lay eggs during late winter and early spring. Surveys of these egg-laying events demonstrate a possible relationship between weather cues and spawning events. We studied the phenology of spotted salamander egg laying in seven vernal pools on the Sewanee domain. We hypothesized that egg masses would be more abundant after a rise in temperature and an increase in precipitation. We also compared egg mass counts among the seven ponds and with data collected in 2010. We counted the cumulative number of egg masses weekly in all seven ponds for six weeks in late February through the end of March 2011. We found that precipitation events and cooler maximum temperatures occurred before the major spawning events. Total egg mass numbers varied greatly among the seven ponds, with the highest number occurring in a pond at the end of Breakfield Road. Egg mass totals from the present season were considerably higher than the totals for 2010. These results demonstrate that there is a relationship between weather patterns and spotted salamander spawning events on top of the Plateau and that the number of egg masses laid varies considerably by pond and year.*

Introduction:

Vernal pools are temporary lentic systems that are formally classified as wetlands. They exist in shallow depressions that are filled with water from melting snow or rainfall in the spring, dry up as spring and summer progress, and may fill again with rainfall until the late summer. Due to periodic dry spells, the vernal pools are not suitable habitat for fish or other predatory animals that require a lasting body of water. However, despite the fluctuating water levels, many species of plants and animals thrive in the environment provided by the vernal pools (Kangas 2005). Regardless of the vernal pool size, which is usually small compared to water reservoirs and lakes, individual vernal pools in close proximity to each other can vary in the number and kinds of taxa that may be supported. (Colburn 2004)

Among the many species endemic to ephemeral pond habitat, the spotted salamander (*Ambystoma maculatum*) is an obligate species that requires vernal pools to complete its life cycle. F. N. Blanchard (1930) formulated a study that focused on the migration of spotted salamanders in southern Michigan, in which he concluded that the species migrate to their natal pools during the first rainfall following the first signs of spring (thawing snow, and rising temperature). This behavior was later studied by O. J. Sexton et al. (1990) to include the affect of temperature and precipitation, which supported Blanchard's results. The study by O. J. Sexton et al. stated that all salamander movement was associated with nocturnal rainfall. Male salamanders are usually the first to visit the pools in the wake of the rainfall season to deposit sperm in the form of spermatophores into the vernal pools (Sexton et al. 1990). This event is later followed by the migration of the female salamanders to the pools. They take up the spermatophores into their bodies and deposit fertilized eggs in masses. These egg masses are usually attached to submerged objects such as fallen tree branches or stable leaf litter.

The eggs take about five to six weeks to develop into free-swimming larvae. A study conducted by C. R. Shoop (1974) concluded that the survivorship of the hatchling into their adult counterparts is dependent upon the developing speed of the larvae. It is assumed to be better for the larvae to develop quickly and leave the pools before they dry out, yet in Shoop's study, there are also advantages for the larvae to slowly develop into adult form. Shoop discussed that the larvae with a longer development stage are more likely candidates to survive to the reproduction period (Shoop 1974). However, there are many confounding factors contributing to the development of the larvae that are not fully understood.

An extensively studied influencing factor is the effect of human interaction with the vernal pools and the consequences of these effects. The immediate biotic factors suitable for the proliferation of the spotted salamanders are vernal pools that do not last long enough for fish to live in, yet last long enough for the larvae to complete their developmental stage and metamorphose into their terrestrial adult form. However, with an explosion of urbanization in rural areas, human activity has become a cause of the disappearance of the vernal pools. Roads and highways have been estimated to affect one-fifth of land area in the United States by fragmenting crucial habitats and degrading the hydrology within environments such as the one belonging to vernal pools (Turtle 2000, and Karraker et al. 2008). The purpose of this study is to determine the preferred location for spotted salamander egg laying and to examine the phenology of the reproductive cycle of the spotted salamander in relation to ambient temperature increase and precipitation. We expected that (1) more egg masses would be laid as a result of greater amounts of precipitation, (2) higher temperatures would facilitate greater amounts of new egg masses, (3) more eggs would be laid in ponds with a higher abundance of invertebrate prey than in ponds without, and (4) fewer egg masses would be found in ponds with less forest cover near urban areas than in ponds with more forest cover in areas where human influence was minimal.

Methods:

Study Sites:

For our study, we visited seven ponds (n=7) on the Cumberland Plateau in Sewanee, Tennessee (35°12′4″N 85°55′17″W). Four of the ponds were located in forested watersheds (Breakfield Pond, Mushroom Pond, Mountain Goat Pond, and Piney Point Pond) (Figures 1-4), while the other three ponds were in more urbanized watersheds (Airport Pond 1, Airport Pond 2, and Airport Pond 3)(Figure 1).

Egg Masses:

On a weekly basis, our group of four divided into two groups of two, and traveled to assigned ponds to count the number of spotted salamander egg masses. Each week one student systematically waded out into each pond (Figure 5) and counted all visible egg masses while another student recorded the data found. As egg masses were found their location was marked with red tape and labeled with the date and number of egg masses found in that location.

Temperature and Precipitation:

Our correspondents in the forestry and geology department on the University of the South recorded the data for temperature and precipitation daily. Once our data of the egg masses were collected from the field, we merged the two sets of data together. The compilation of the two sets of data was then used to determine whether changes in temperature and precipitation affect the number of egg masses found within the ponds and the development of the egg masses.

Results:

We sampled seven vernal pools on the Sewanee Domain for egg masses of the spotted salamander. Of the pools sampled, we found that Breakfield pond had the highest number of egg masses found overall (Figure 7). Airport 1 pond had the second most egg masses, and Piney Point, Mushroom, and Goat Trail had the progressively less, respectively. Airport 2 and Airport 3 had very few egg masses overall. The number of egg masses increased on March 2nd, March 9th, and March 16th. The egg masses began to decrease on March 23rd and continued to decrease on March 30th.

Precipitation events occurred on February 20th, 24th, 28th, March 6th, 10th, 14th, 23rd, 26th and 29th, the largest measures of precipitation being documented on March 6th and March 26th (Figure 11). These precipitation events were followed by a decrease in maximum temperature over the next three to seven days. The March 6th drop in temperature was followed by a period of increasing overall temperature until March 24th (Figure 12).

Discussion:

Our data showed that the majority of the egg masses laid during the first of the month were laid after the two substantial rain events of February that occurred on the 26^{th} and the 28^{th}. There were also larger spawning events after the precipitation events on the 6^{th} and on the 14^{th} of March (Figure 11). The data supported our hypothesis that more egg masses would be laid as a result of increased precipitation. However, with this increased precipitation came increased temperatures because of the weather patterns of the study sites. In the Cumberland Plateau area, especially in the late winter and early spring, short rain and thunderstorm events move from west to east in front of the boundary of a warm front and a cold front. As the cold front pushes east, the temperatures reach a peak of high temperature, and following this relatively high temperature is a precipitation event. Because these highest relative temperatures occur just before the increase in precipitation, our hypothesis regarding higher maximum temperatures facilitating greater numbers of added egg masses was supported as well. As shown by Figure 12, the maximum temperature is highest relatively preceding the greatest numbers of added egg masses. Compared to the egg mass counts from the previous season, the egg counts are significantly higher this season due to the increased amount of precipitation and increased average maximum temperature (Figures 8, 9, and 10).

Bryan et al. found that Breakfield, Mushroom, and Airport 3 ponds had the greatest mean abundance of invertebrates, especially small copepods, which the salamander larvae have been observed feeding upon in the spring of 2011. Since the only pond in the group of high invertebrate abundances was Breakfield pond, it was the only pond that supported our hypothesis that more egg masses would be laid in ponds with a higher mean abundance of invertebrate prey. Airport 1 and Piney Point ponds had the second and third highest egg mass counts respectively, but these ponds did not support our hypothesis about the relation of egg masses to invertebrate prey. From these relationships another study could be conducted to determine the survivorship of the salamander larvae in ponds with a high abundance of invertebrates compared to ponds with a low abundance of invertebrates.

Spotted salamanders use substrate in ponds such as trees, fallen branches, and even fallen trees (Figure 6) to lay their eggs. Ponds found in more forested areas usually have more of these objects in the pond on which the salamanders can attach their egg masses than the ponds found in the more urbanized areas, and this led us to hypothesize that more egg masses would be laid in ponds found outside of urbanized areas. Figure 7 shows that our hypothesis was supported. Breakfield, Mushroom, and Piney Point pond were the three ponds in more forested areas, and they were found to have the first, third and fourth highest egg mass counts respectively. Airport 1 pond was found to have the second highest abundance of egg masses, but was located in a more urbanized area closer to roads than the forested ponds. These results show that even though the proximity to roads is a factor in the amount of egg masses laid, the amount of forest cover is also a factor. The Airport 1 pond was located in a moderately wooded area, so the amount of tree cover could have affected the amount of eggs laid in that pond which had been considered one of the ponds in an urbanized area.

While the quality of breeding sites are important to the population growth of spotted salamanders, the surrounding upland area is also important. Human land use causes disturbances in urbanized ponds such as, roads, trash, and noise pollution. The presence of human activities, mainly roads, near vernal pools has been studied to show negative effects on the habitats of the spotted salamander. One well-studied factor as to why roads are detrimental to the vernal pools is the usage of deicing agents on the roads. About twenty-six states in the United States rely on deicing chemicals such as sodium chloride (road salt) to make traveling safer in the wintertime. However, during the spring when the snow melts, the chemical runoff streams into adjacent areas. This runoff then flows into depressions that may become vernal pools after rainfalls. Road salt has been documented to have an adverse affect on the ionic and solute composition in rivers, disturbing the vertical mixing of water in lakes, lowering the densities of benthic invertebrate and lessening the diversity of stream-dwelling macroinvertebrates - overall decreasing the community biomass. (Karraker et al. 2008) This may result in a crippled environment in which the spotted salamander cannot survive.

A more direct affect of the road salt is that species such as the spotted salamander have permeable skin, which renderes it highly responsive to road salt, especially when the skin is the man organ used for respiration and osmoregulation of osmolar balance in a saline environment. (Shoemaker and Nagy 1977) Studies by Turtle (2000) and Karraker et al. (2008) have concluded that not only does high salinity affect the survivorship of spotted salamander during embryonic stage, but it also may cause abnormalities of the species. Turtle concluded that the full list of effects of road salt on the amphibians is not fully understood, but it is probable that vernal pools may be more sensitive to the roadside pollutant, especially ponds that are located within 50m of a visible road. They will more likely interact with snowmelt and storm runoff from the roads than ponds found further from the roads. (Turtle 2000)

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Figure 1: Spatial location of ephemeral ponds located in the area of Airport Rd. in Sewanee, TN Spring 2011. (A) Airport 1, (B) Airport 2, (C) Airport 3, (D) Goat Trail pond.

Figure 2: Breakfield Rd. ephemeral pond in Sewanee, TN Spring 2011.

Figure 3: Mushroom ephemeral pond in Sewanee, TN Spring 2011.

Figure 4: Piney Point ephemeral pond in Sewanee, TN 2011.

Figure 5: Gear worn by student to wade through the pond water while performing egg mass count in Sewanee, TN Spring 2011.

Figure 6: Popular spotted salamander egg mass deposited in fallen tree area in Breakfield Rd. pond in Sewanee, TN Spring 2011.

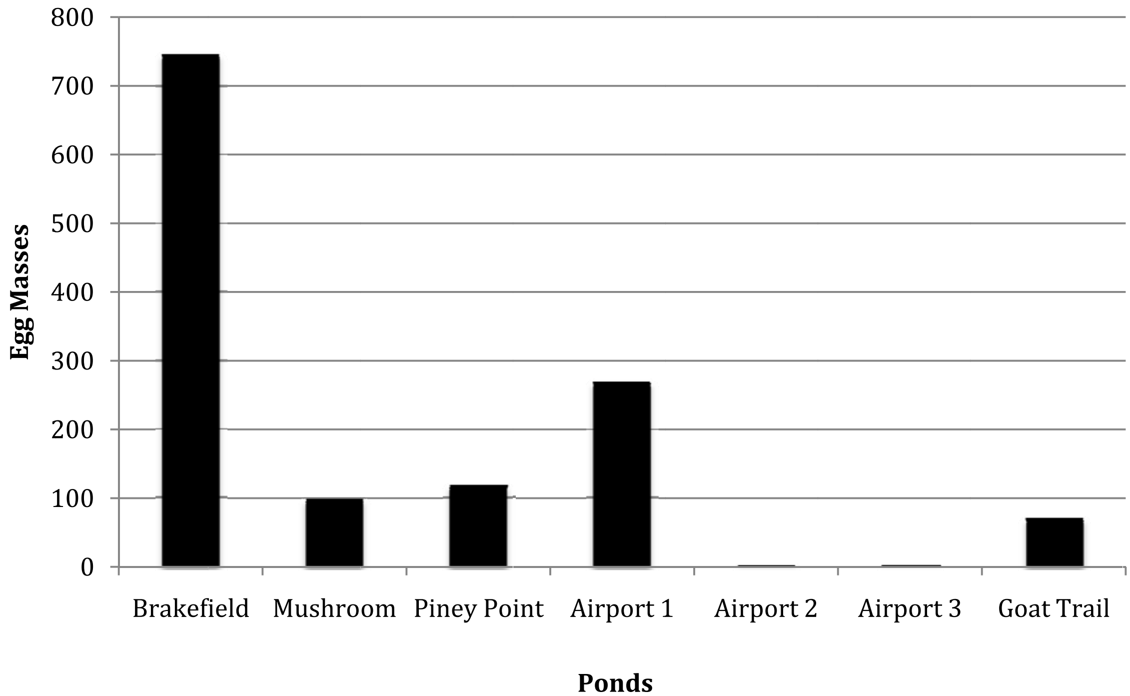

Figure 7: Maximum numbers of egg masses found in ephemeral ponds located in Sewanee, TN Spring 2011.

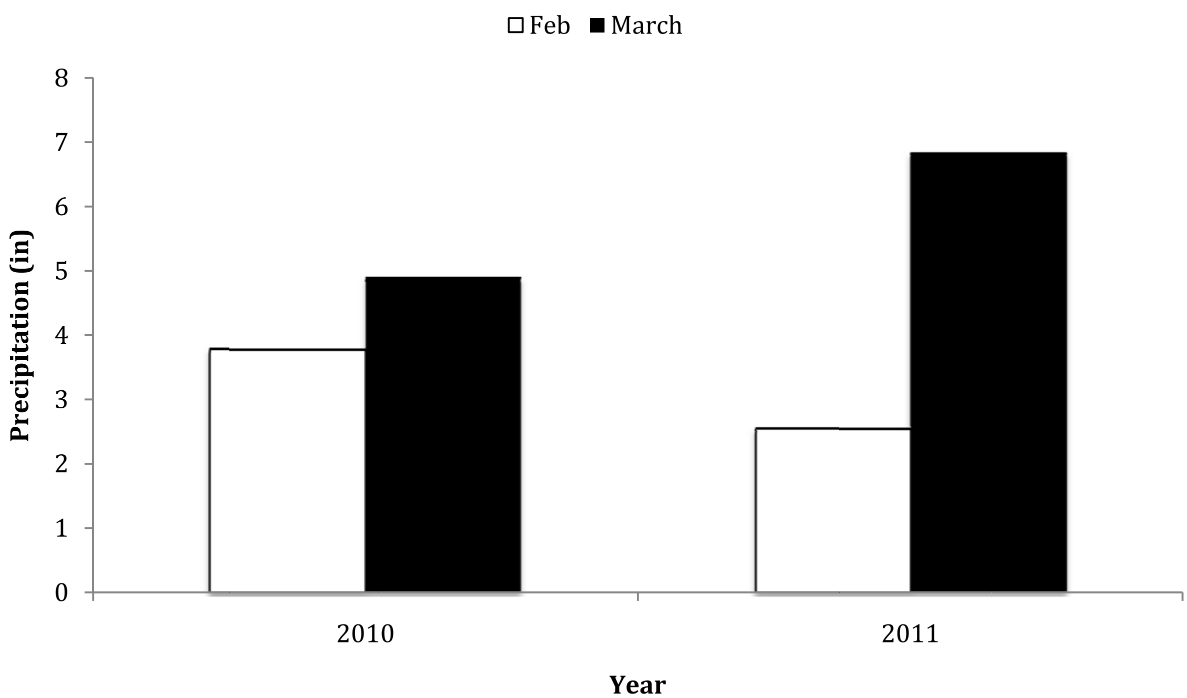

Figure 8: Comparison of precipitation for 2010 and 2011 in the months of February and March in Sewanee, TN.

Figure 9: Comparison of average maximum temperatures for 2010 and 2011 in the months of February and March in Sewanee, TN.

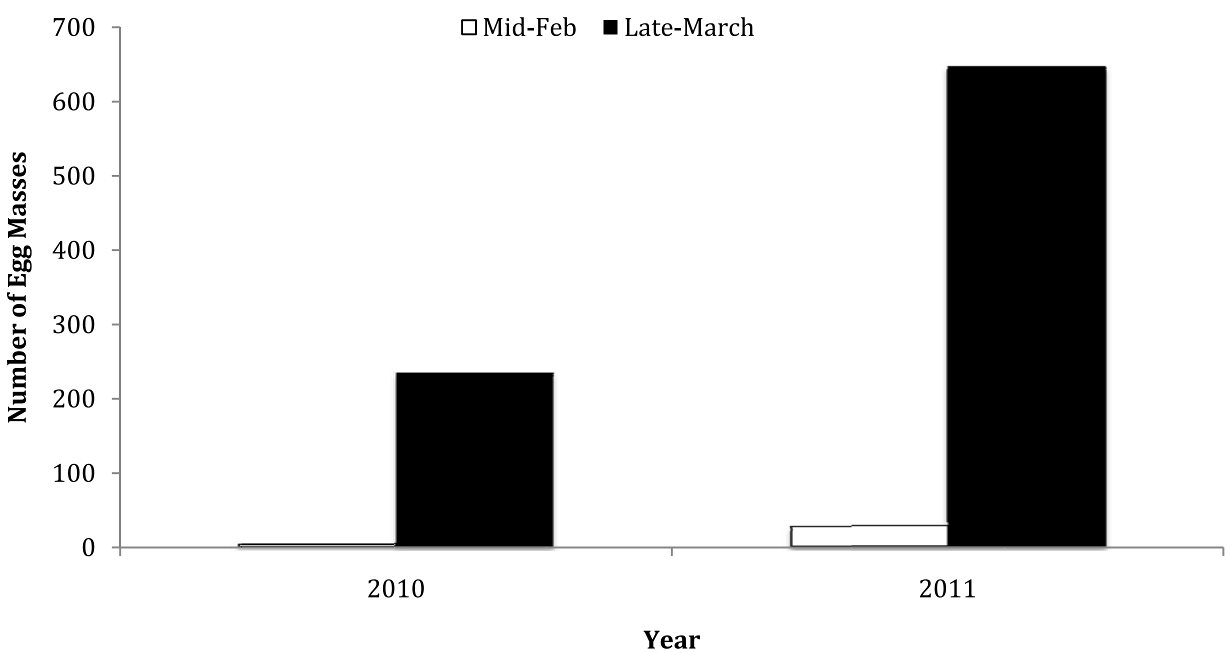

Figure 10: Comparison of egg masses laid for 2010 and 2011 during mid-February and late-March in the ephemeral ponds studied.

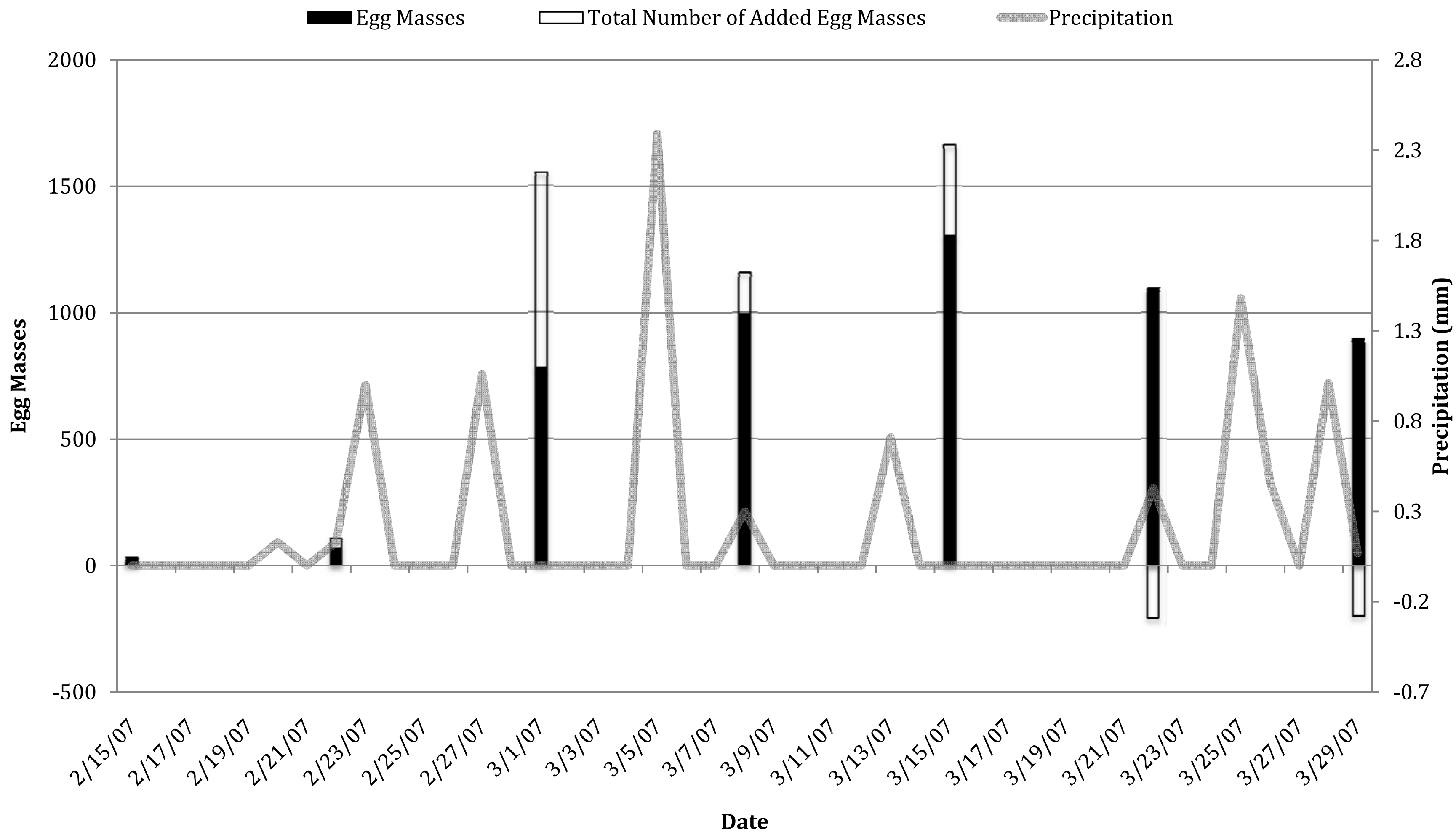

Figure 11: Precipitation trend compared with number of egg masses found in ephemeral ponds (n=7) on Sewanee, TN Spring 2011.

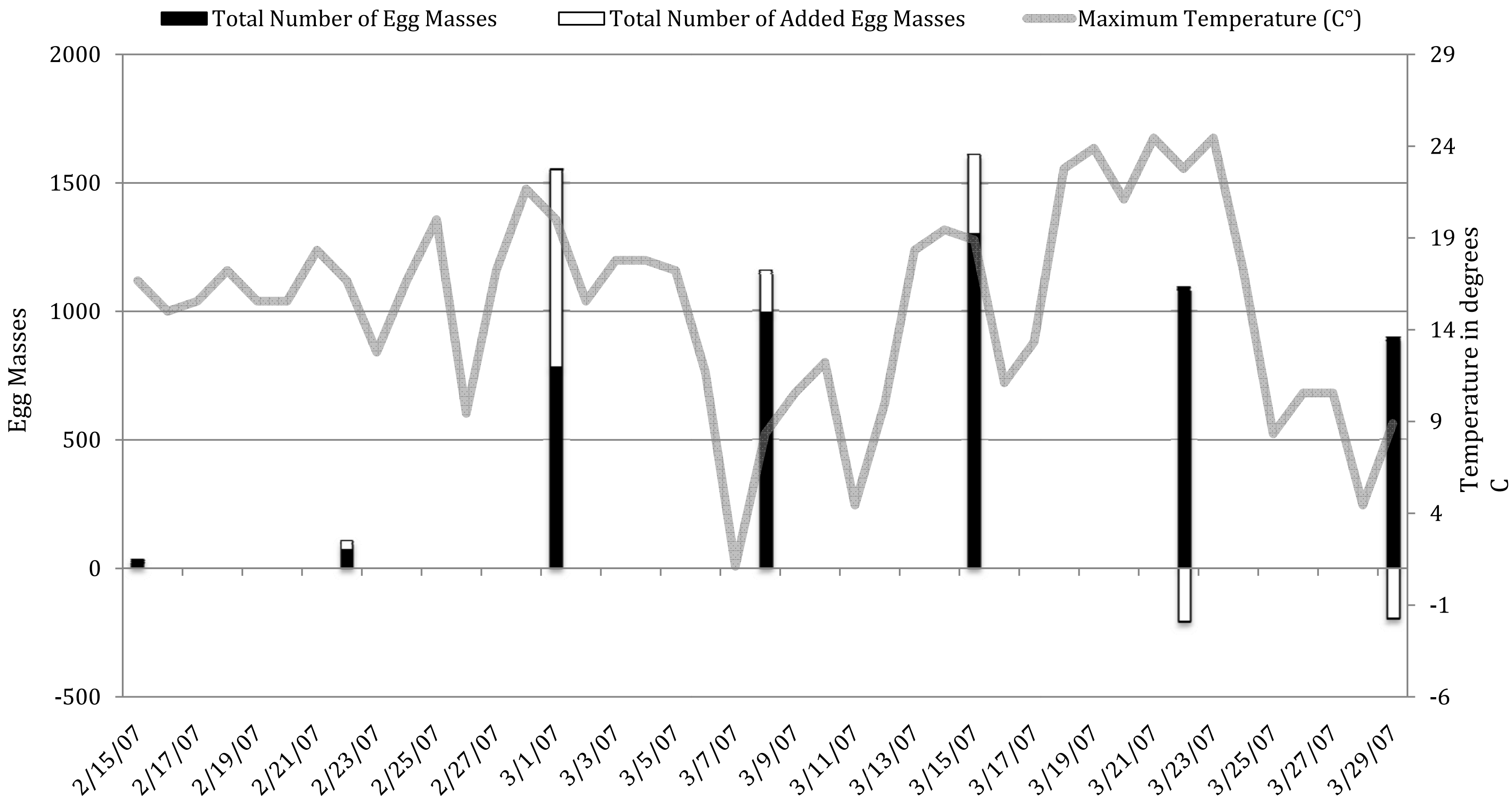

Figure 12: Maximum temperature trend compared with number of egg masses found in ephemeral ponds (n=7) on Sewanee, TN Spring 2011.