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**Abstract**

The emergence times of larval eastern tiger salamanders, *Ambystoma tigrinum tigrinum*, in two vernal in Brookhaven National Laboratory, Upton, NY, was investigated as related to the local precipitation and temperature.  The study was conducted in July and August of 2001, 2003 and 2004 using drift-fence arrays and coverboard-capture techniques. Salamanders were weighed, measured and released after capture. The correlation between tiger salamander migration, temperature and weather was measured using the Pearson's Product Moment Coefficient. It was found that there was a statistically significant relationship between salamander emergence times and precipitation. There was no significant relationship between temperature and emergence.  In 2003 and 2004 it was also concluded that the precipitation levels, and thus pool-drying rate, influenced population sizes and length and weight on emergence.

## Introduction

The Brookhaven National Laboratory (BNL) located in Upton, New York, remains one of the last areas in New York State with a thriving population of the eastern tiger salamander, Ambystoma tigrinum tigrinum. The Laboratory site, comprised of 2.130 ha of pine barren and mixed pine oak forest, has been spared the intensive development of the rest of the region, creating a refuge for many threatened and endangered species. With numerous vernal pools and wetlands, BNL continues to provide the salamanders with a great deal of viable habitat.

The tiger salamander, the second largest terrestrial salamander in the US, (Petranka 1998) arrive at vernal pools from December to early May to breed (Petranka 1998). Egg clusters on Long Island are laid in masses of an average 52 ova and are attached to twigs and weeds in the breeding ponds (Petranka 1998).

Vernal Pools are defined as small, precipitation-filled wetlands that usually exist during the most critical periods of the amphibian development cycle (Zedlera, 2003). They play an interregnal role in the reproductive success of many salamander species, including the tiger salamander. These temporary pools give the developing larvae a haven free from predators such as fish, which require more permanent bodies of water (Zedlera, 2003). The drying cycle and geographic location of most vernal pools allow them to stay fishless, providing specialized breeding habitats for many species of invertebrate and other

The study was conducted under a New York State DEC Endangered and Threatened Species License (number ESP 04 – 0186). Surveying was conducted from 8

July to 8 August in 2001 and 2003 and continued in 2004 from 1 July to 31 July 2004. It remains ongoing as part of a continuing effort to establish a comprehensive management strategy for the conservation and protection of the tiger salamanders on the BNL site. This study hopes to determine how the temperature and precipitation levels of the last few years have affected the emergence times of the larval salamanders from two vernal pools, referred to here as Pond A and Pond B.

## Methods

*Study Area*

Pond A is a vernal pool with an approximate area of .172 ha at its highest flood mark. Canopy cover was minimal as was aquatic vegetation. The surrounding terrestrial vegetation was primarily made up of mixed grassland. Pond B, a smaller vernal pool, with an area of .151ha, was situated in a pine/oak forest. It had emergent aquatic vegetation covering approximately 75% of its surface.

Weather recordings were provided by the National Oceanic and Atmospheric Administration (NOAA) observatory located on BNL site. Temperature and precipitation readings were taken over a 24-hour period from 08:00h to 08:00h daily. Maximum and minimum temperatures were recorded from which mean temperature was estimated.

*Monitoring Technique*

The weight (gm) and snout-vent length (mm) (SVL) of captured salamanders were taken using a Acculab GSI-200 electronic scale and Plasti-Cal digital calipers. Once measurements were taken, all salamanders were immediately released a short distance away from the buckets in which they were found.

The emergence of salamanders was monitored during the first year of study using coverboards surrounding Pond A. No data was collected at pond B for this year. Coverboards of 1.2x1.2m sheet of 1cm in thick plywood were placed five meters from the edge of the water at ten meter intervals with a second and third row of boards ten and fifteen meters from the water.

Emergence data for study years 2003 and 2004 were based upon the capture of salamander in newly constructed drift-fence arrays. Four terrestrial drift fences were constructed at each pond. The fences were made of aluminum flashing buried 15cm into the soil and were located at the northwest, northeast, southwest and southeast corners of each pond. The arrays consisted of two flashing segments, each with a length of 3 m and above ground height of .5m. Segments were placed on either side of a central bucket with additional buckets at each end of flashing. All buckets were buried even with the ground at a distance of 3 meters from the high-water mark.

To minimize predation and desiccation, bucket lids were attached to 3 cm high wooden stilts to shield captured salamanders from view and reduce evaporation. Additionally, 5cm wire mesh squares were installed atop each bucket and two 12.7cm lengths of PVC piping, 3.81cm in diameter, were placed in each bucket to provide refuge for the salamanders. Traps were checked daily at mid morning.

A Lincoln-Peterson index was used to estimate the total number of salamanders emerging from the ponds. The index uses a proportion comparing the number of animals caught in the arrays (total length per pond = 26.88m) by the total perimeter of the pond.

The correlation between tiger salamander migration, temperature and weather was measured using the Pearson's product moment coefficient. The test was run using Microsoft Excel, 2000 edition.

## Results

It was noted that during the three years of the survey, the numbers and sizes of emerging salamanders varied from summer to summer as did the time periods in which they emerged as shown in Table 1 and Figure 1 + 2.

The number of emerging salamanders vary from year to year affecting recruitment. For example, in 2003 an estimated 2319 salamander metamorphs migrated from Pond A, whereas an estimated 578 emerged from the same pond the following year (Table 1). Interestingly enough, while more salamanders emerged in 2003, their average weight was less than in either 2001 or 2004.

Emergence time also varied yearly. In 2001 larvae began to exit the pond in mid-July with numbers falling off in early August (fig 1). In 2003 a large number of salamanders emerged from 22 July to 8 Aug. The earliest emergence occurred in 2004, with salamanders beginning their migration in early June.

Mean temperature in all three study periods only varied by approximately one degree. The average temperatures were 22.0 °C in 2002, 23.10 °C in 2003 and 22.1 °C in 2004. Precipitation levels were 7.8cm in 2001, 13.2cm in 2003 and 7.77cm in 2004 (Table 2). Pearson Product Moment coefficient was used to estimate the correlation between emergence and precipitation, with a confidence level of $P>.05$. For 2001, the r coefficient was below the critical value of $r = .367$ and was deemed not to be significant. In 2003, however, the correlation between precipitation and emergence for Pond A and B was $r=.579$ and $r=.694$ respectively, ($n=32$), showing there was a positive correlation between daily emergence and precipitation levels. Likewise, a positive correlation was found in 2004, with Pond A r=.487 and Pond B r=.323. In both years, a correlation was found between movement at Pond A and movement at Pond B, r=0.523 in 2003 and r= .648 in 2004.

The Pearson's Correlation Coefficient values between temperature and emergence were not correlated in any year.

## Discussion

The results show that there is a relationship between precipitation and the migration of salamander from the pond. No significant relationship was found for precipitation and movement in 2001, but this may be blamed on imprecise capture technique.

In 2003 and 2004, *Ambystoma tigrinum tigrinum* larvae emergence was correlated to periods of rainfall. The conclusion that precipitation is one determining factor in the timing of the larval migration from the water compliments the findings of Sexton et al. (1990) who noted that the movements of adults returning to the pond were primarily associated with rainfall.

The amounts of rainfall are almost certainly also responsible for the times and sizes at which the salamanders begin to emerge. To illustrate, in 2004 Pond B was dry by the last week in July (pers. obs), far earlier than in 2003. The average SVL for these salamanders was almost 20mm less than the previous year (Table 1). Without water to sustain them, the only possible survivors of drying vernal pools are those with the shortest larval times (Shoop 1974) and it has been noted that related species will metamorphose at an earlier stages of development to avoid desiccation, cutting back on growth so as to escape the pools. (Rowe & Dunson 1995).

It was expected that higher temperatures might encourage the larvae out of the water at a earlier date, however the there was no significant correlation between emergence and temperature. It has also been theorized that the higher temperatures would cause a change in larvae oxygen demand and result in earlier emergence at an earlier stage of development. (Burggren & Infantino, 1994). This does not seem to be the case in this study.

Average temperature in the three summers only varied by approximately a degree (Table 2). This might not have been enough to significantly influence salamander behavior. It may be that the influence temperature has on larval salamanders requires further investigation over a longer period of uninterrupted time.

**Acknowledgement**

I would like to thank the Department of Energy and BNL for giving me the opportunity to participate in the Science Undergraduate Laboratory Internship (SULI) internship program, Dr. Timothy Green and Jeremy Feinberg, my mentors, for putting up with me, and the kind people at the NOAA. observatory for all their help. Also, thanks to go out to Val Titus for advice concerning statistics as well as to my fellow interns, Kristine Hoffmann, Wendy Finn, Frank Smith, Stephen Goodyear, and Susan Costa for summer-long assistance and advice.

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| | **Pond A** | | | **Pond B** | |
|---|---|---|---|---|---|
| ***Year*** | *2001* | *2003* | *2004* | *2003* | *2004* |
| ***Captured*** | 43 | 301 | 75 | 5 | 7 |
| ***Estimated Total*** | N/A | 2319 | 578 | 36 | 50 |
| ***Mean SVL (mm)*** | 62.28 | 63.82 | 64.29 | 70.26 | 50.6 |
| ***Mean Weight (gm)*** | 10.18 | 9.03 | 12.63 | 12.64 | 5.11 |

**Table 1** The number of emergent salamanders captured in each pond for 2001, 2003, and 2004 along with the calculated mean SVL and weight. Due to the capture technique used in 2001, the estimate of total salamanders emerging from Pond A in 2001 could not be calculated with any degree of accuracy.

| | **Mean Temperature (°C)** | **Total Precipitation (cm)** |
|---|---|---|
| **2001** | 22.00 | 7.80 |
| **2003** | 23.10 | 13.20 |
| **2004** | 22.10 | 7.77 |

**Table 2** The mean temperature and total precipitation for the study periods in all three years. The summer with the highest temperature was 2003, which was also the year of the greatest total precipitation.

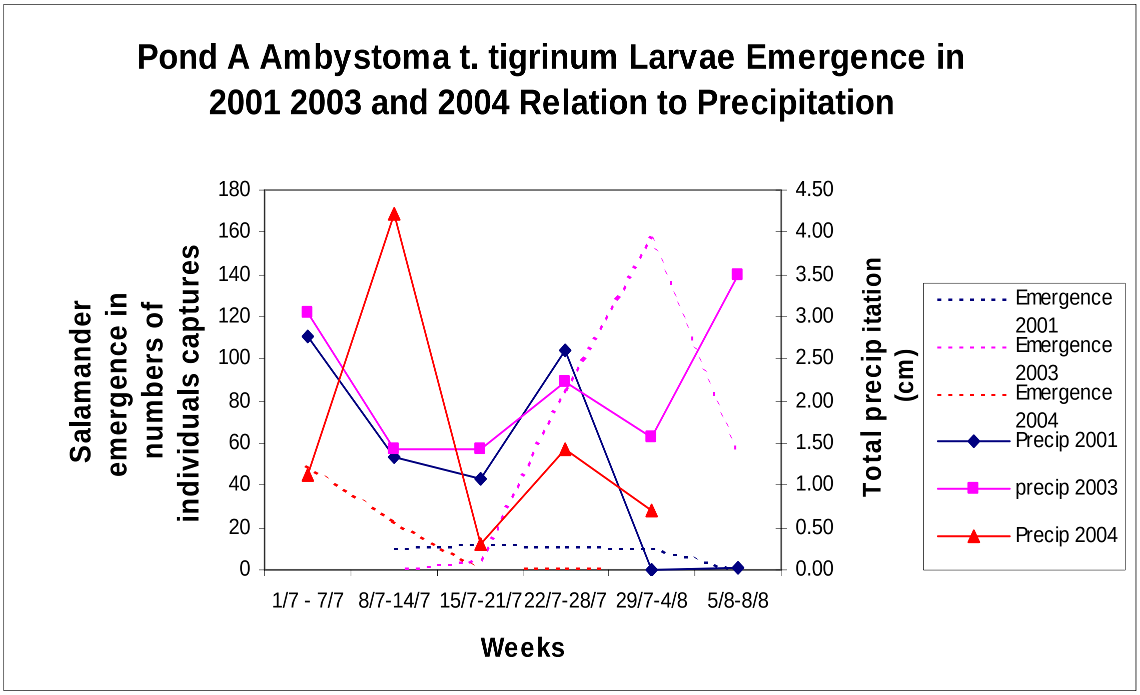


**Figure 1** Shows the numbers of salamanders captured under coverboards in 2001 and drift fence arrays during 2003 and 2004 at Pond A on a weekly basis. Also shown is total rainfall (cm) for each of the sampling weeks as recorded by the NOAA station.

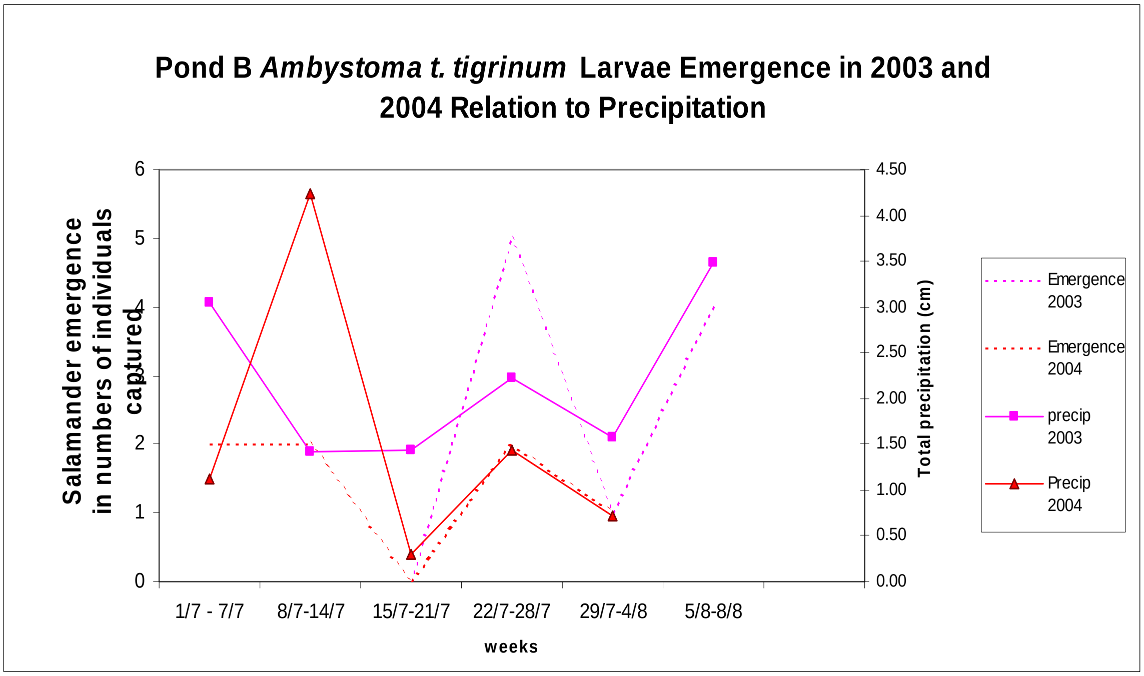


**Figure 2** Shows the numbers of salamanders captured in the drift fence arrays during 2003 and 2004 at Pond B on a weekly basis. Also shown is total rainfall (cm) as recorded by the NOAA station.

**Pond A Ambystoma t. tigrinum Larvae emergence in 2001, 2003 and 2004 as related average Temperature**

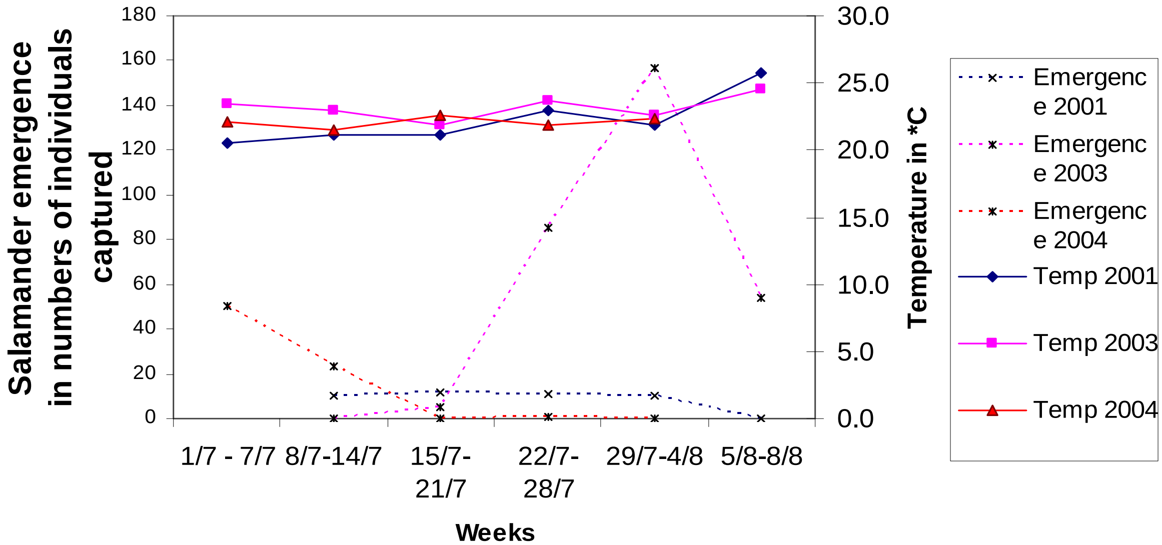


**Figure 3** The number of salamanders captured weekly from Pond A in 2001, 2003 and 2004 as related to the average temperature. The chart shows little connection between temperature and emergence.

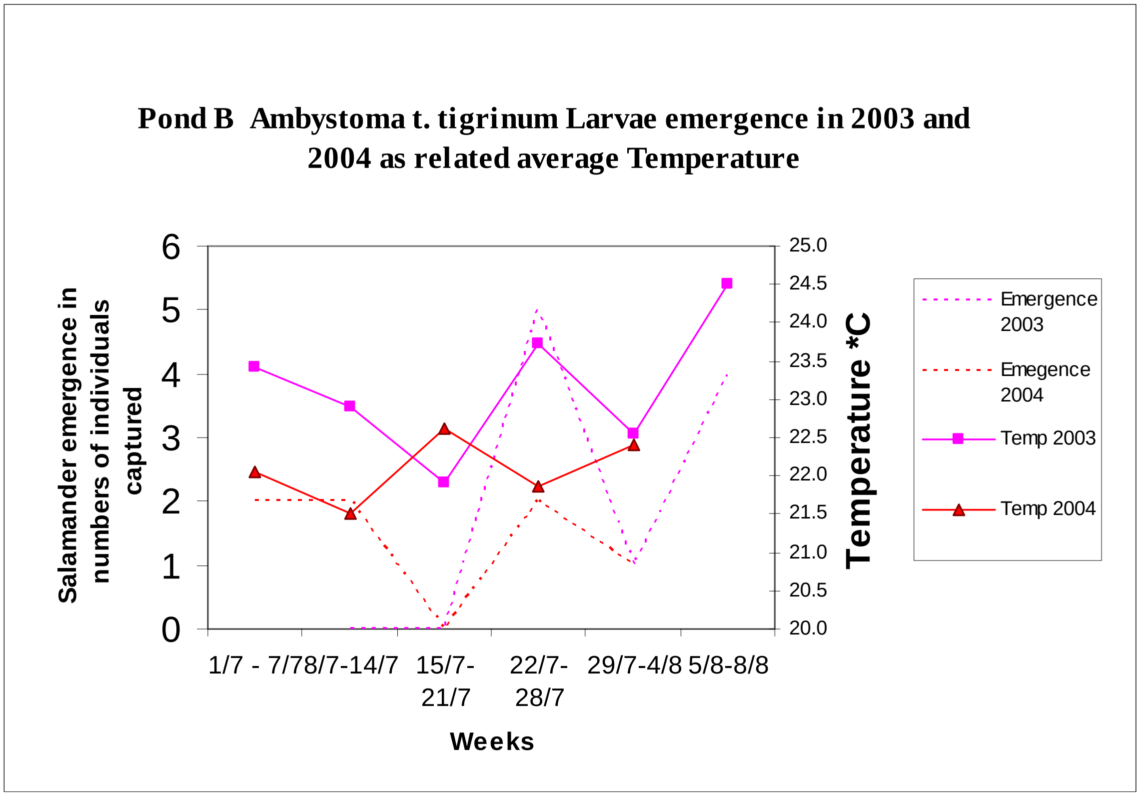


**Figure 4** The number of salamanders captured weekly from Pond B in 2003 and 2004 as related to the average temperature. The chart shows little connection between temperature and emergence.

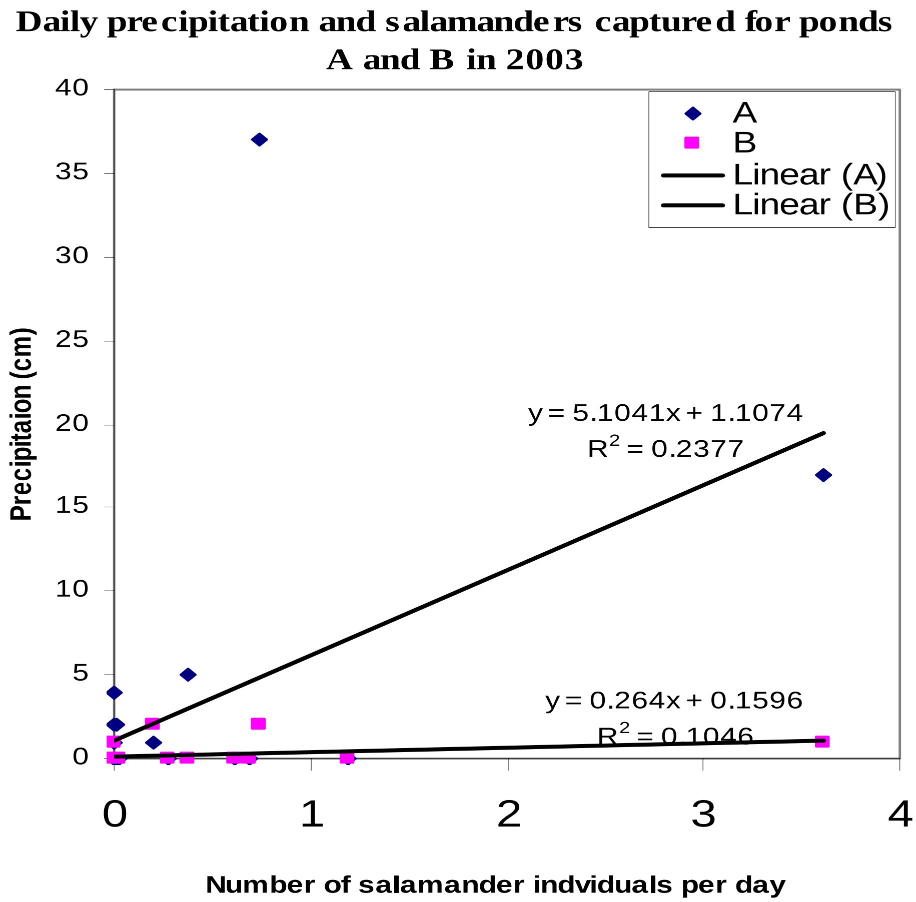


**Figure 5.** Scatter gram of the daily precipitation and salamander capture in Ponds A and B in 2003. Trend line was plotted and $r^2$ values calculated.

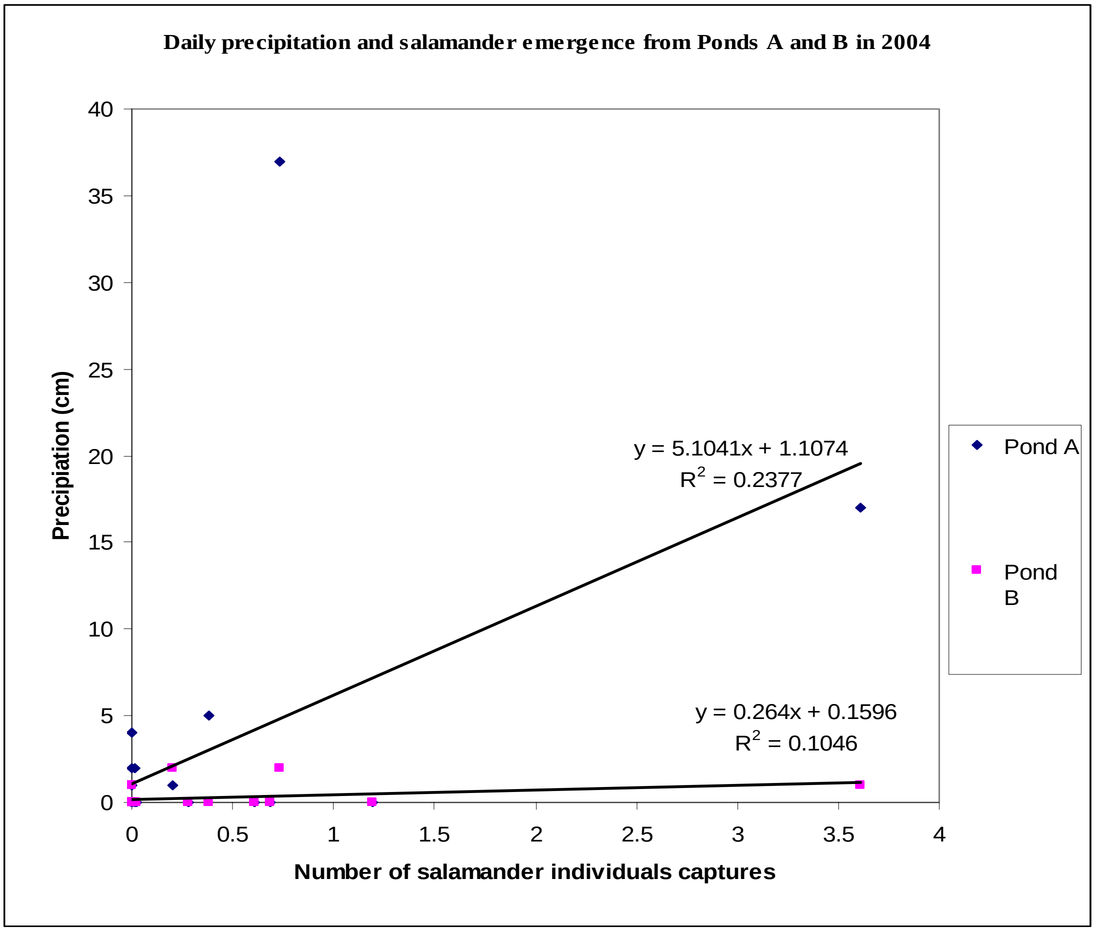


**Figure 6.** Scatter gram of the daily precipitation and salamander capture in Ponds A and B in 2004. Trend line was plotted and $r^2$ values calculated.