Kinematics Of Feeding Behavior In The American Toad: Terrestrial Versus Elevated Prey

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Abstract

Since 2011 the Dickinson College Farm has been used as a living laboratory for student researchers, investigating organisms within an Integrated Pest Management (IPM) system. IPM is a technique used to control pest insects without use of harmful pesticides. Recent research investigating diet composition of the American toad suggests toads consume a variety of invertebrate organisms on the Dickinson College Farm including some pest insects. The proportion of pest insects susceptible to predation by toads is, however, currently unknown. This project addresses this question, studying the kinematics of toad feeding behavior to characterize terrestrial and elevated prey capture. To measure these parameters toads high-speed videography (500 fps) was filmed using a Miro Phantom EZ1 camera and presented with live prey, crickets, at varying heights above ground. Video analysis was carried out using Tracker video analysis software. The movement of particular landmarks on each toad was monitored over time and included: the upper jaw tip, lower jaw tip, tip of the tongue, jaw joint, tip of coccyx, knee, ankle, and wrist. Preliminary analysis indicates that predation of insects elevated off the ground requires different body positions relative to predation of terrestrial insects and that significant differences exist for variables including: time of maximum excursion, duration of approach,lunge distance, maximum tongue reach, initial angle of attack, maximum angle of hind leg extension, and maximum forelimb excursion. These results support that American toads are effective predators of pest insects, as they have been documented capturing prey at distances 2.3 times their body length.

Methods

Toads captured from the Dickinson College Farm were collected and transported to a laboratory setting in a climate-controlled vehicle.

All toads were maintained in the glass terraria tipped up at an angle less than ten degrees to allow pooling of water on one end but allow the toad to move easily between the sides. The bottom of each terrarium was lined with paper towel. Terraria were cleaned once per week or when soiled (Martin 1991). To clean terraria all soiled paper was removed and any residual waste flushed out with water before wiping down terraria with dilute chlorhexidine solution. This was allowed to sit for ten to fifteen minutes before being rinsed again and supplied with fresh paper and water.

Toads were kept at 22-24 degrees Celsius in order of facilitate optimal tongue extension (Deban and Lappin 2011) and were fed every other day with crickets, drosophila, or worms, offered between two to six prey items at a time depending on body size (Robins and Rogers 2003). Dietary supplements containing calcium and phosphorus were given dusted on crickets (Michaels et al. 2014) in addition to vitamin D3 provided, using UVB light treatments (Browne et al. 2009).

Predation mechanics and vertical prey capture ability were assessed by recording feeding encounters with high-speed video. Toads were fasted for a minimum of two days prior to any recorded feeding encounters to ensure toads were equally interested in prey items and should show normal predatory behavior (Secor and Faulkner 2002). Video was filmed at 500 frames per second using a Miro Phantom EZ1 camera positioned to clearly view the lateral side of each toad as well as the prey item. A mirror, mounted at a 45º angle allowed simultaneous observation of the dorsal view of the toad. Toads were filmed in front of a 1cm x 1cm gridded background for scale during later analysis of video. Additional Illumination was provided by a Plus Series LED 500 Dracast lamp. Toads were placed on a tray lined with a moist paper towel and were allowed to rest in the dark, under a covering, for approximately one to two minutes. Once the prey item was in place and the additional lighting and camera were turned on the cover was removed and the feeding encounter recorded.

All video was analyzed using Tracker video analysis software. The position of the following landmarks was marked on each frame of video using trackers point mass feature: the tip of upper jaw, tip of lower jaw, tip of the tongue, jaw joint, tip of coccyx, knee, ankle, and wrist.

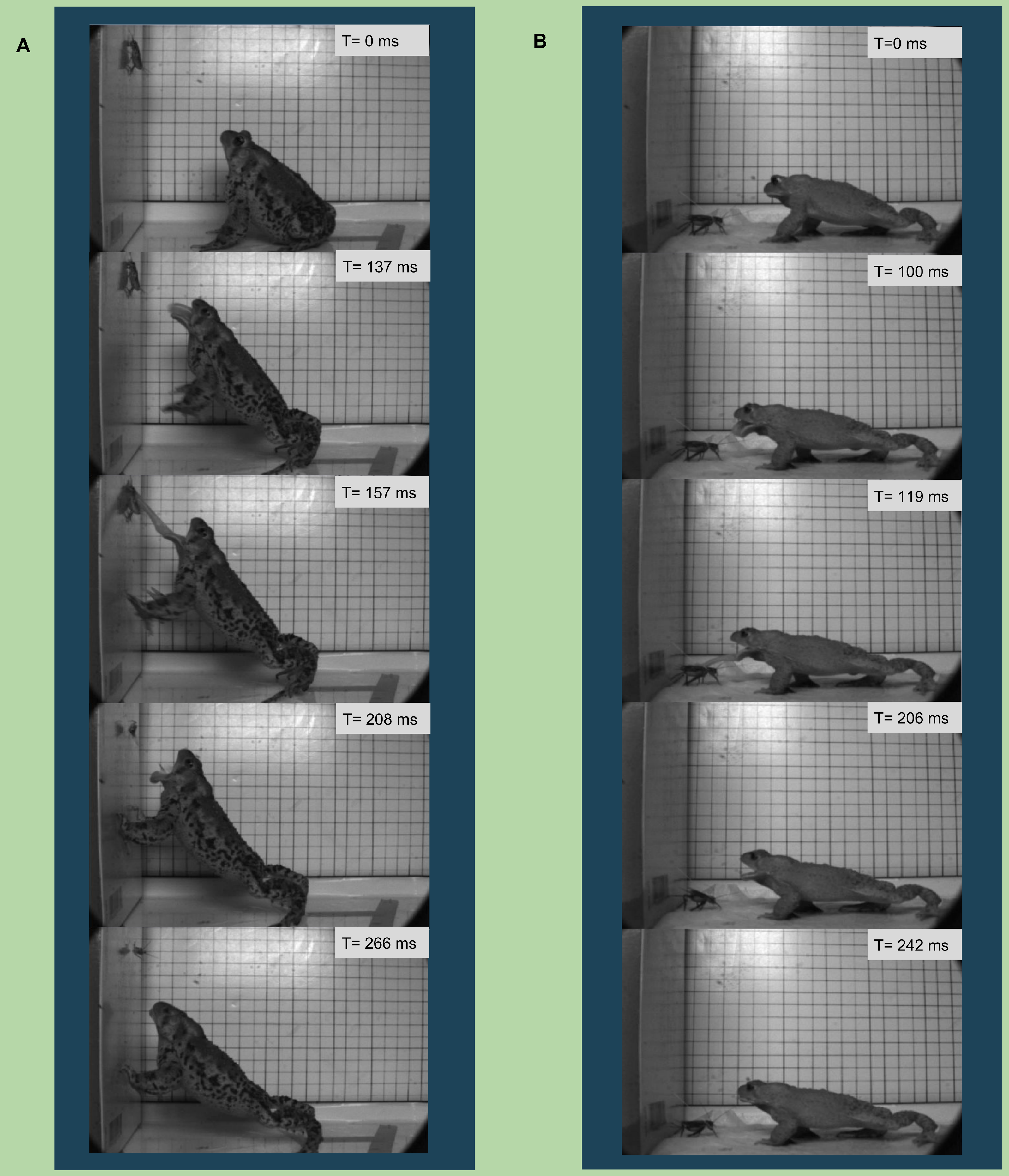


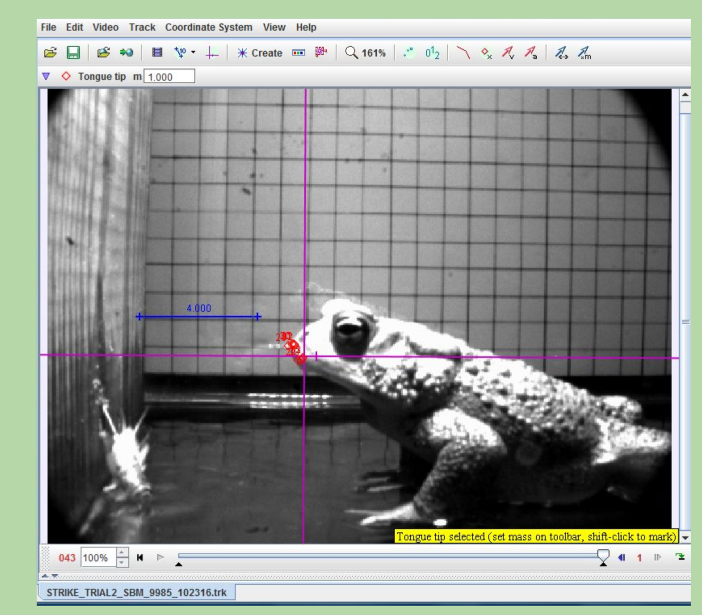
Figure 1. Selected frames from video of feeding encounters where prey items were offered 1.5cm from the ground (A) and 13cm from the ground (B)

Table 1. Sample size (N), range, mean, and standard error (SE) for kinematic variables from terrestrial and elevated feeding encounters. P value from T test comparing terrestrial and elevated results for each parameter is included in the last column.

	Terrestrial				Elevated				
	N	Range	Mean	SE	N	Range	Mean	SE	P value
Onset of tongue protraction (ms)	10	53.57-152.77	104.36	10.74	10	103.17-146.82	130.66	4.49	0.0793
Onset of mouth opening (ms)	10	49.6-146.82	100.19	10.54	10	99.2-142.85	127.09	4.57	0.0793
Time of prey contact (ms)	9	69.44-172.61	123.67	11.19	10	117.06-166.66	144.96	4.74	0.158
Time of max tongue reach (ms)	10	69.44-172.61	120.43	10.76	10	117.06-166.66	147.50	5.21	0.0913
Time of maximum gape (ms)	10	111.10-220.22	165.07	10.23	10	136.90-212.29	189.92	7.14	0.0685
Time of maximum excursion (ms)	10	75.39-202.37	142.65	12.82	10	134.91-218.24	185.34	8.53	0.0377*
Duration of approach (ms)	10	75.39-202.37	142.65	12.82	10	134.91-218.24	185.34	8.53	0.0377*
Duration of mouth opening (ms)	10	41.66-95.23	64.97	4.61	10	37.70-82.24	62.83	3.82	1
Duration of tongue protraction (ms)	10	7.94-23.81	16.27	1.53	10	11.88-21.82	16.84	1.09	0.881
maximum gape angle (º)	10	76.8-144.1	117.86	6.42	10	74.7-127.3	108.34	4.71	0.227
Increase in gape angle (º)	10	65.8-133.4	108.24	6.60	10	65.6-121.7	98.67	5.42	0.320
Initial distance to prey (cm)	10	3.32-12.92	6.93	0.9723	10	7.997-15.08	11.90	0.7348	0.138
Lunge distance (cm)	10	.09295-8.074	3.38	0.7794	10	3.61-11.29	8.04	0.7834	0.0008*
Maximum tongue reach (cm)	10	2.02-5.64	4.17	0.3712	10	3.51-6.79	5.03	0.3192	0.0005*
Initial body position angle (º)	10	5.8-45.4	20.63	3.57	10	23.8-54.9	42	2.96	0.0064
Initial angle of attack (º)	10	11.9-82.4	28.09	6.44	10	28.1-51	36.39	2.38	0.0279*
Maximum angle of hind leg extension (º)	10	0-94.3	47.76	8.38	9	31-144.6	87.58	11.51	0.0442*
Maximum forelimb excursion (cm)	10	0-4.03	1.11	0.4348	9	3.14-13.15	9.77	0.9993	0.0021*
Prey distance: onset of tongue protraction (cm)	10	2.58-7.00	4.47	0.4527	10	3.90-8.11	5.71	0.4645	0.121

The following measures were recorded from video analyzed in tracker with onset of forward head movement used as t = 0 : (1) onset of forelimb lifting, (2) onset of tongue protraction, (3) onset of mouth opening, (4) time of prey contact, (5) time of maximum gape, (6) time of maximum excursion, (7) Duration of approach, (8) duration of mouth opening, (9) duration of tongue protraction, (10) maximum gape angle, (11) initial distance to prey, (12) lunge distance, (13) maximum tongue reach, (14) initial angle of attack, (15) maximum angle of hind leg extension, (16) maximum forelimb excursion, (17) distance from prey item at onset of tongue protraction, (18) strike location

The statistical program SAS was used to analyze data from videos. For non-parametric comparisons of means the NPAR 1 WAY SAS procedure was used. A Wilcoxon non-parametric two sided t test was used to compare terrestrial and elevated parameters. Pearson correlation, PROC CORR in SAS, was used to assess correlation between prey height and other measured variables.



Discussion

Parameters displaying significant differences between terrestrial and elevated prey capture include: time of maximum excursion, duration of approach, lunge distance, maximum tongue reach, initial angle of attack, maximum angle of hind leg extension, and maximum forelimb excursion.

Pearson correlation indicated that most parameters were not correlated to prey height. The only measures to show correlation with prey height were maximum forelimb extension, initial body position angle, lunge distance, and initial distance from prey. Maximum forelimb extension showed a positive correlation to prey height (*P*=0.76507, P=0.0163, N=9). Significant positive correlation was also shown for initial body position angle (*P*=0.81194, P=0.0043, N=10). Lunge distance displayed a positive correlation with prey height (*P*=0.75372, p=0.0118, N=10). Finally a positive correlation was also found between initial distance from prey item and prey height (*P*=0.87541, P=0.0009, N=10).

The correlation between prey height and lunge distance and the correlation between prey height and initial distance from prey are to be expected. Increased prey height would naturally increase the initial distance from prey item and the distance needed to be covered in order to capture said prey item. The correlation between prey height and maximum forelimb extension and prey height and initial body position angle are more interesting. This correlation suggests that initial body position is extremely important in the capture of elevated prey items and that the forelimb is very involved in the capture process. The significant increase in initial angle of attack, maximum angle of hind leg extension, and maximum forelimb excursion from elevated values also supports this idea. This research indicates that up to a certain height toads may act as predators of elevated pest insects

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