Near-field Behaviors of Carp at Bubble Barriers

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UDC version

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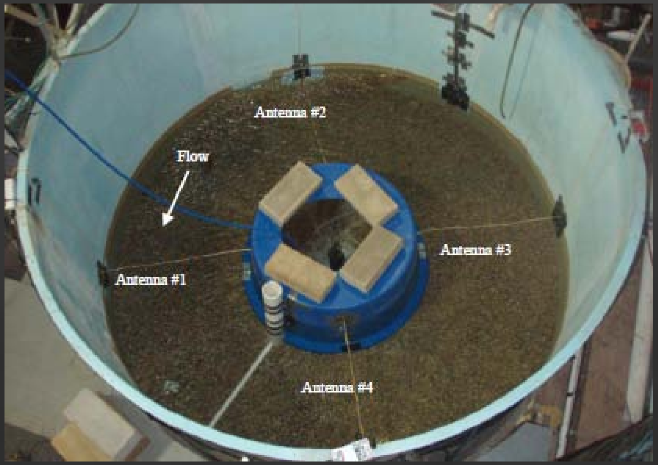
Funding / Premise

- University of Minnesota **UROP** funded - Spring 2011
- Addendum experiment supplementing Daniel Zielinski's M.S. thesis work.
- ***Bubble Barrier Technologies (Submitted March 2011)***
  - Exploiting hearing specialization of cyprinid fish in development of effective acoustic bubble barriers.
  - Detailed documentation of the physical field characteristics of bubble barriers.
  - Developed 3 successive barrier designs.
  - Substantial replication.
  - Reduced barrier passage of common carp by ~75%, with no decrease in net movement.
  - Fish dispersion follows random walk model.

Zielinski experiments

- Used PIT tracking system in circular barrier testing tanks (design by Jon Svendsen).
  - 1 tagged fish and 2 non-tagged fish
    - Assumed shoaling behavior
  - 3 meter diameter tanks
    - 1 meter diameter interior barrier
    - 1 meter wide “stream”



- **Great** for studying net movement characteristics of small groups of juvenile carp.

- **Poor for observing near-field behaviors.**

Focus: near-field behavior

- The barriers have an effect on carp movement, but are still being crossed quite frequently.
  - What distance from the barrier does avoidance behavior happen?
  - How can we improve this aversive effect and increase barrier efficacy?

- Which sensory system (or combination of systems) controls the avoidance behavior?
  - **Auditory** – (Inner ear) sound
    - Zielinski concluded most important.
  - **Lateralis –** (Lateral line system) water velocity
  - **Visual –** (Eyes) light

- Vision is isolated in this experiment using IR capable cameras.

Critical Approach Distance (CAD)

- Logical framework to simplify data collection
  - Eliminates need to track fish position continuously during analysis
- Assumption:
  - Upon encountering barrier in test environment, fish will make choice to cross barrier or turn around.
- **Distance at which fish turns away from barrier = CAD**
  - Measured at distal end of caudal peduncle
    - Observer's best interpretation of position in relation to reference scale
- **This distance is a proxy for the distance at which the physical fields of the barrier become aversive to the carp.**

Hypotheses:

1.) There will be differences in CAD distribution between Day / Night treatments

- Indicating visual component

2.) CAD distribution will reflect acoustic SPL field of the mark 3 barrier

- Indicating auditory component

3.) CAD distribution will reflect water velocity field of the mark 3 barrier

- Indicating lateralis component

4.) There will be a relationship between CAD and time.

- Indicating "learning curve"
  - Shy / Bold continuum individual differences
  - Mutable senses

The following figures and tables are from Zielinski 2011

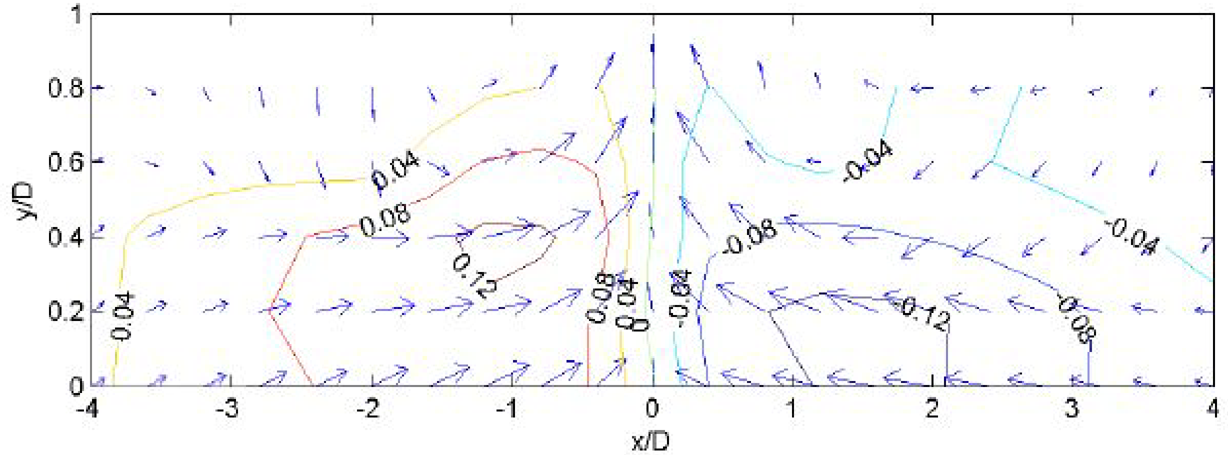


Figure 2-10. Velocity field for coarse-bubble diffuser at 2.5 $Ls^{-1}m^{-1}$ and a depth D=25cm

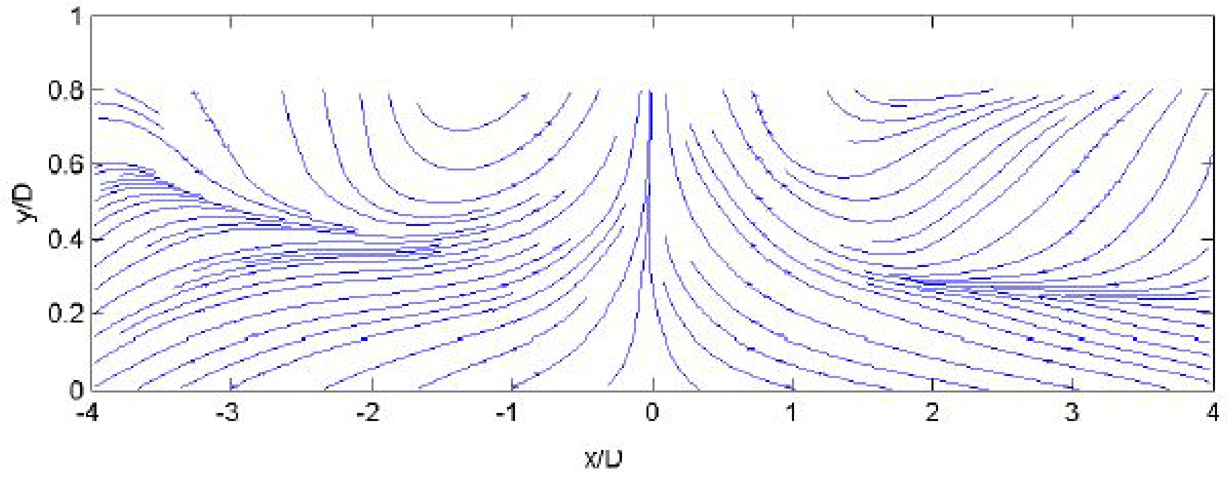


Figure 2-11. Streamline plot of coarse-bubble diffuser at 2.5 $Ls^{-1}m^{-1}$ and a depth D=25cm

SPL (Sound Pressure Level) Field

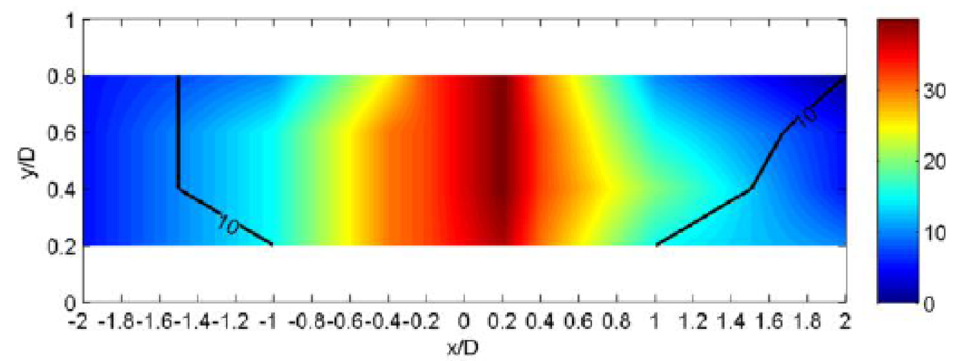


Figure 2-17. SPL above background for coarse-bubble diffuser at a depth D=25 cm (scale is in dB)

SPL Attenuation Plot

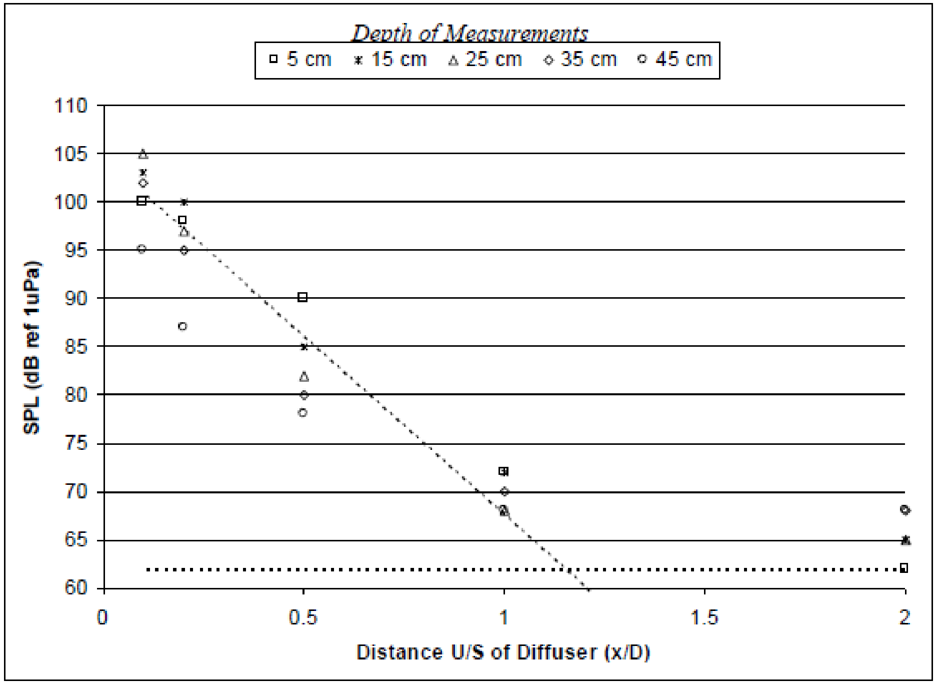


Figure 2-18. Attenuation plot for fine-bubble diffuser at depth D = 50 cm

Table 2-1
Flow field characteristics of diffusers

Diffuser Type	Flow-rate ($Ls^{-1}m^{-1}$)	Depth (cm)	Maximum Velocity (cm/s)	Stagnation Point Location (X,Y)	Kolmogorov Scale (mm)
Fine-Bubble	1	25	8	(+/-1,0.6)	0.08
	2.5	25	16	(+/-1,0.75)	0.05
	2.8	25	17	(+/-0.8,0.6)	0.06
	2.5	50	13	(+/-1.5,0.75)	0.07
	2.8	50	16	(+/-2,0.75)	0.05
Coarse-Bubble	2.5	25	12	(+/-1,>0.8)	0.05
	2.8	25	13	(+/-1.5,>0.8)	0.04

Table 2-2
Maximum SPL of each diffuser

Diffuser Type	Flow-rate ($Ls^{-1}m^{-1}$)	Depth (cm)	Maximum SPL (dB)	Influence Distance (x/D)
Fine-Bubble	1	25	90	+/- 0.6
	2.5	25	100	+/- 1.0
	2.8	25	112	+/- 1.6
	2.5	50	98	+/- 0.6
	2.8	50	110	+/- 1.2
Coarse-Bubble	2.5	25	120	+/- 1.6
	2.8	25	125	> +/- 2.0

Equipment

- High speed digital video capture equipment.
  - Submerged horizontal FOV
  - IR and daylight camera heads
  - PIXCI Image capture software
  - 30 fps day/10 fps night.
  - Circular referencing

- Raw footage compressed and analyzed with:
  - Open-source virtualDub version 1.9.11 video editing software.

- PIT tag system can not be run in conjunction due to signal interference.

- Thanks to Daniel and SAFL for loan of this system.

Experimental Design

- Apparatus is as described by Zielinski 2011, except for addition of:
  - **Reference scale**
    - Steel rod stock embedded in gravel
    - Egg crate on opposing wall
  - **Camera head**
  - **IR illuminators**
    - 2x incandescent spotlights
- From carp's point of view, trial structure is identical to that used in Zielinski experiments.
- Fish came from same population used in Zielinski work, and had not been tested for a month or more.

Mark 3 barrier


VITEK

Experimental Design

- Replication: Balanced Daylight and Darkness Trials (n=3)
  - Night
    - 1
    - 2
    - 3
  - Day
    - 1
    - 2
    - 3
- **Total 6 trials**

- Pseudo-replicated scan sampling trial:
  - 3 fish
    - 1 tagged
    - 2 non-tagged
  - 10 min acclimatization before T_0
  - Left in until 25 event replications observed
    - ~ 1-3 Hrs
  - Up to 3 individual events per group event

“A video speaks a thousand words”

Examples

Attempts - d2_5

Examples

In barrier attempt – d3_9

Examples

Cross upstream parallel – n2_12

Examples

Cross downstream oblique – n3_18

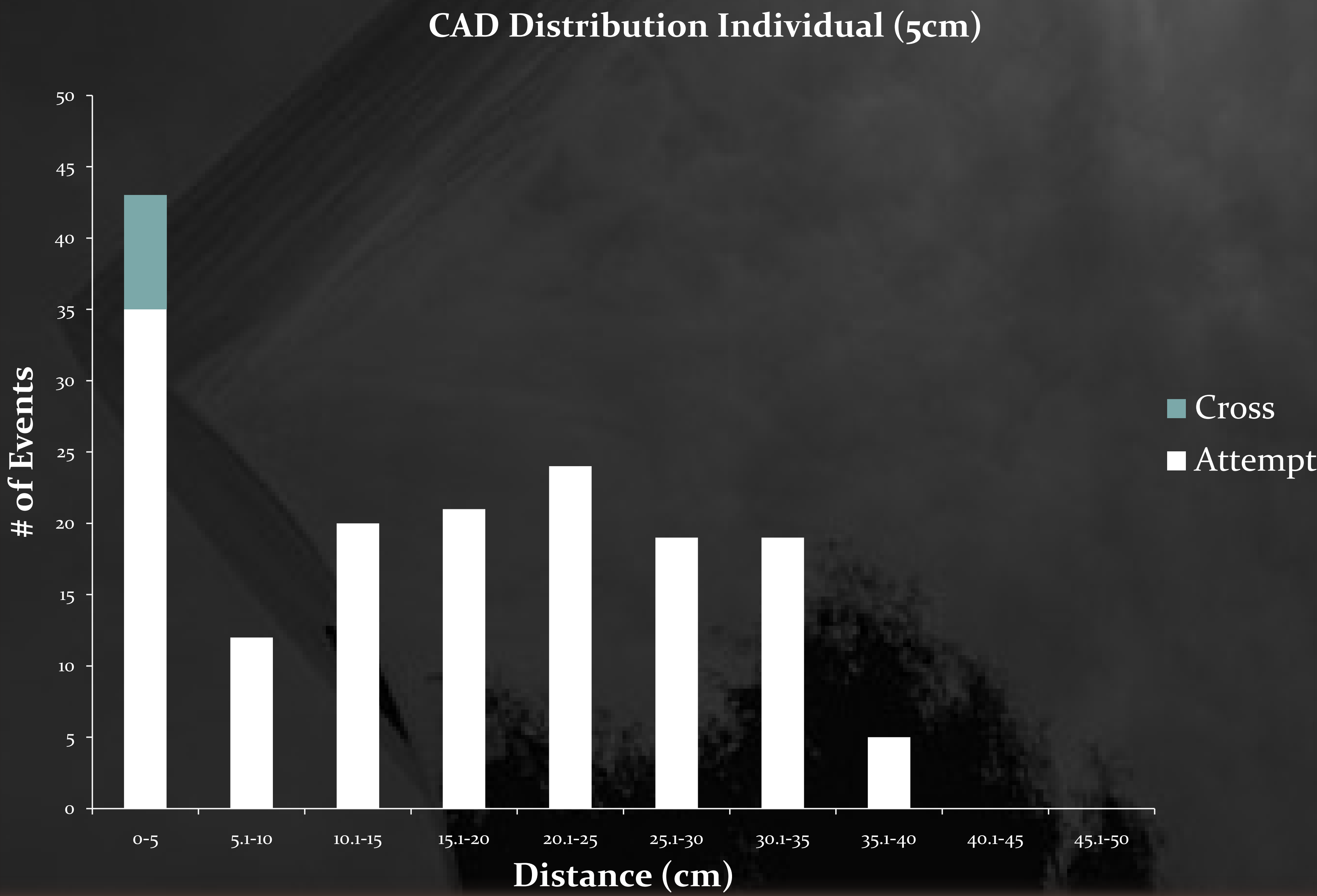
Examples

Cross via jump? – n3_23j

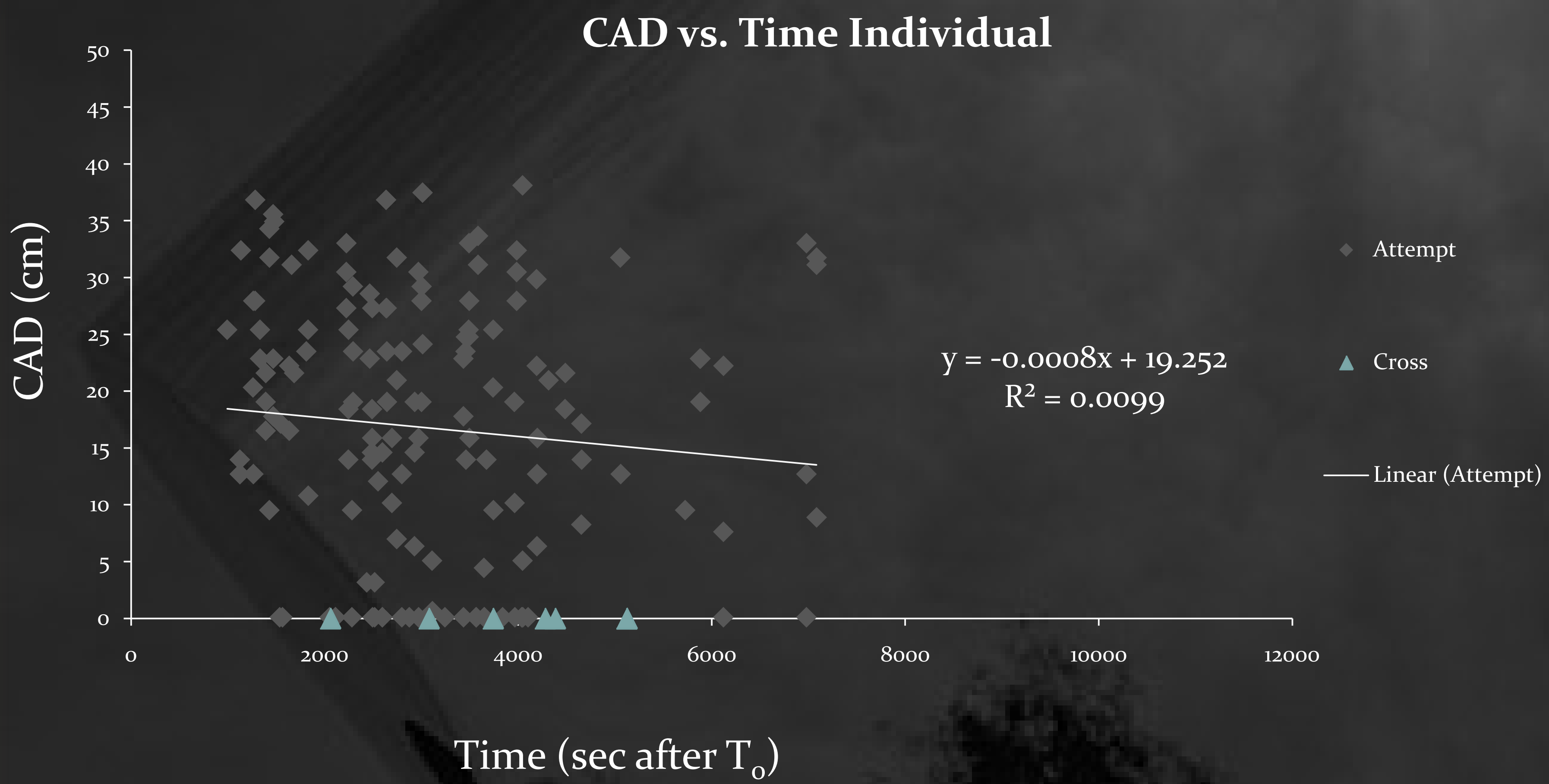
Analysis

- Footage scored for each individual attempt / crossing event for following attributes:
  - Day / Night
  - Attempt / Cross
  - CAD distance (cm)
  - Grouping status
    - Solitary
    - Group of 2
    - Group of 3
  - Crossing orientation
    - Parallel to flow
    - Olique to flow or jump
- Distribution of CAD distances (10cm and 5cm intervals)
  - Group mean
  - Individual
- CAD vs. Time plot
- Median CAD distance
- Grouping and crossing stats

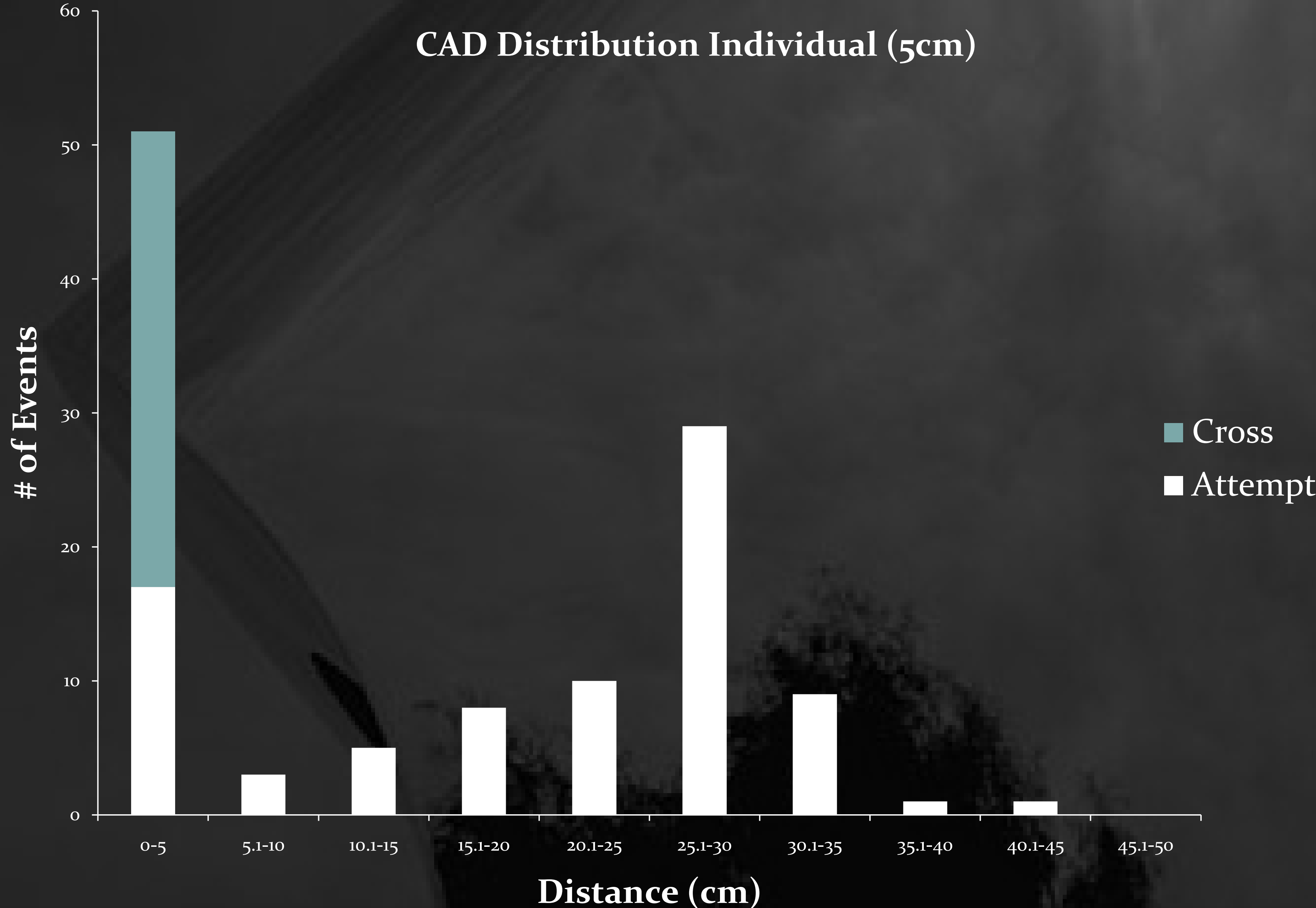
Day Trials Aggregate



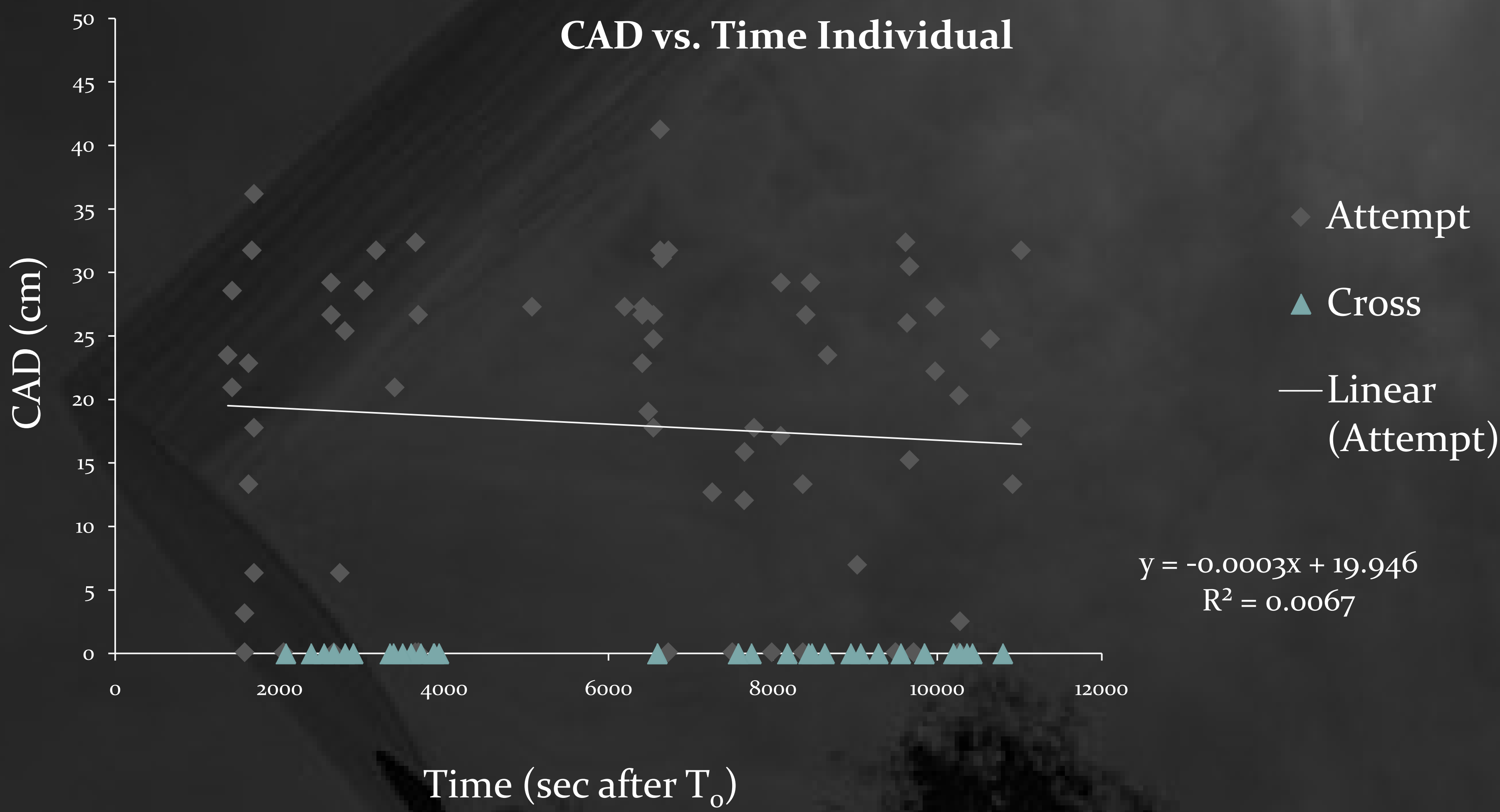
Day Trials Aggregate



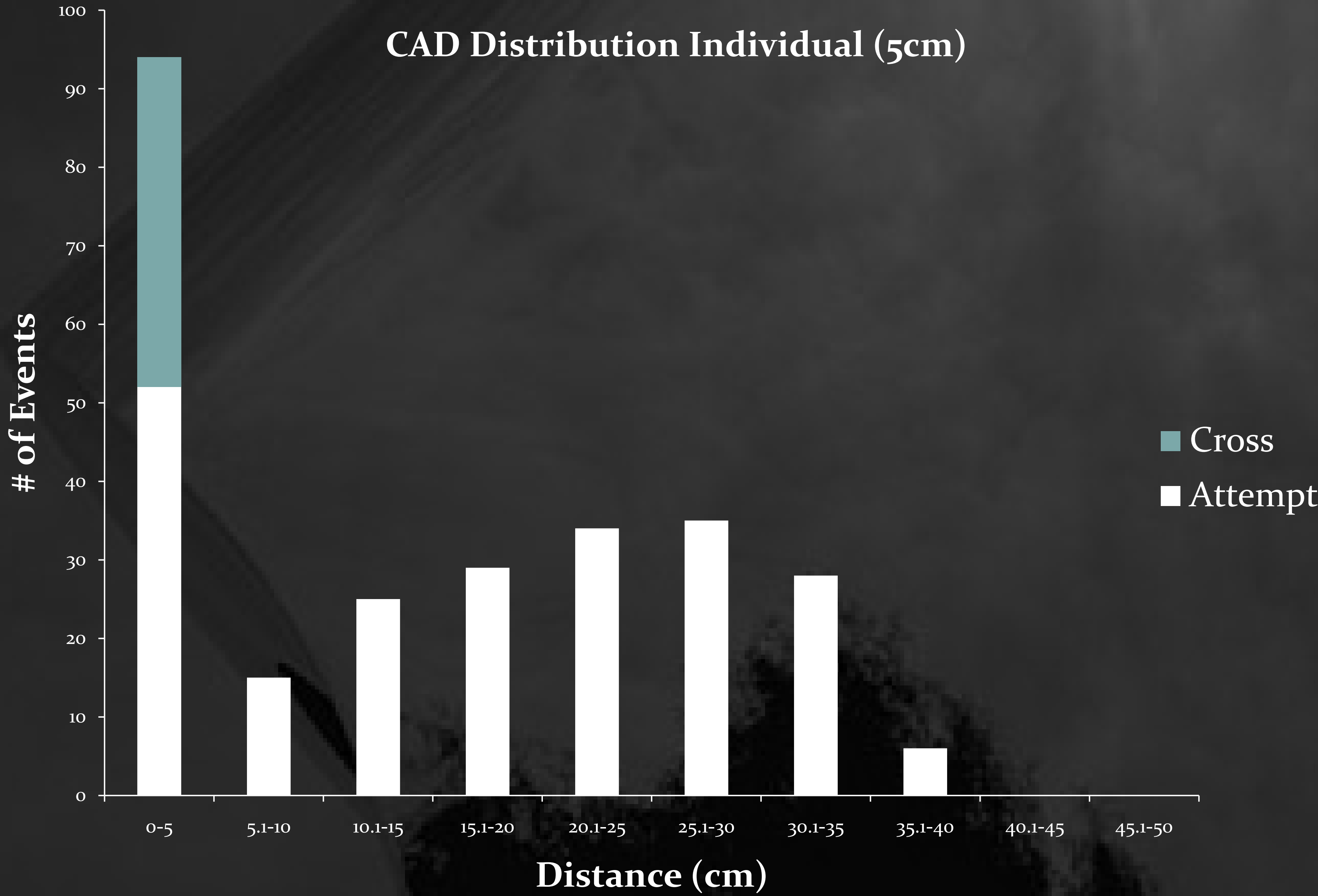
Night Trials Aggregate



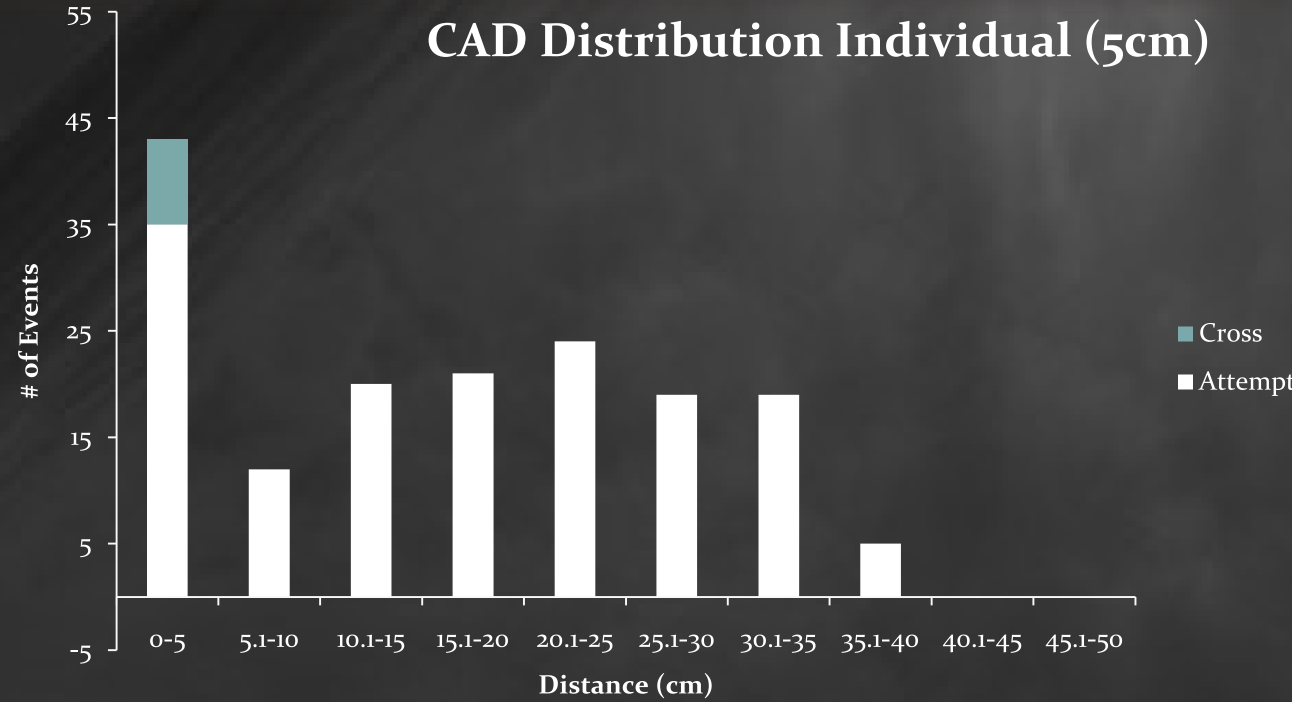
Night Trials Aggregate



All Trials Aggregate

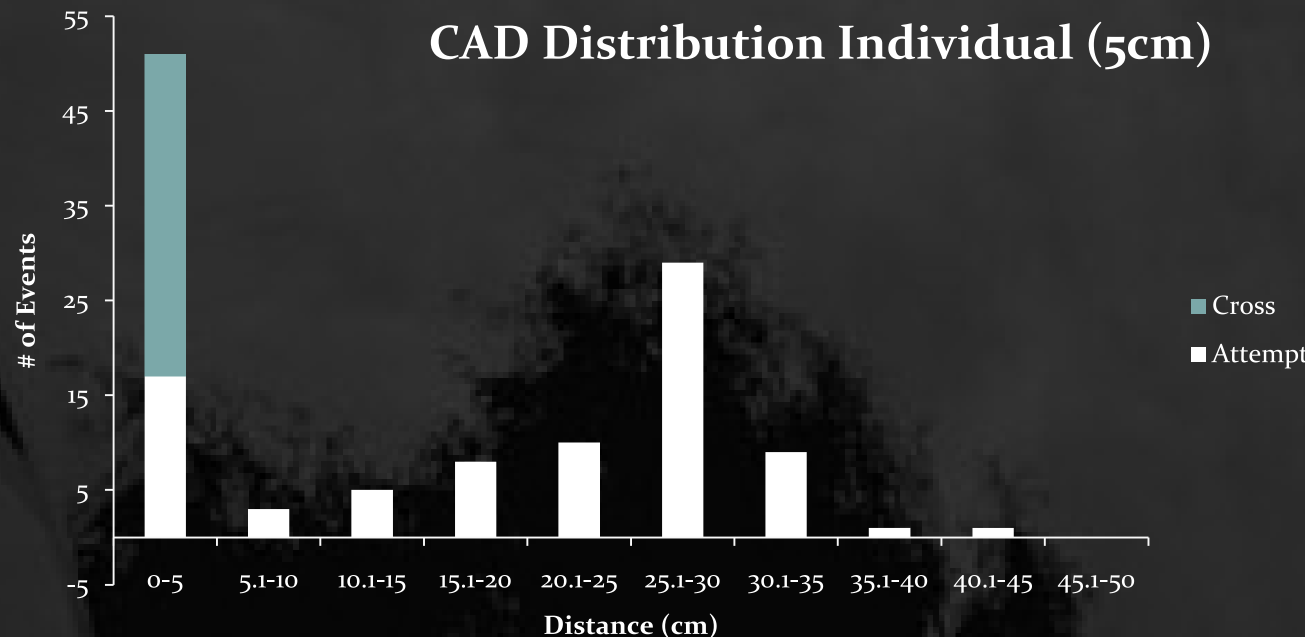


Day



CAD Distribution Individual (5cm)
# of Events
55
45
35
25
15
5
-5
0-5
5.1-10
10.1-15
15.1-20
20.1-25
25.1-30
30.1-35
35.1-40
40.1-45
45.1-50
Distance (cm)
Cross
Attempt

Night



CAD Distribution Individual (5cm)
# of Events
55
45
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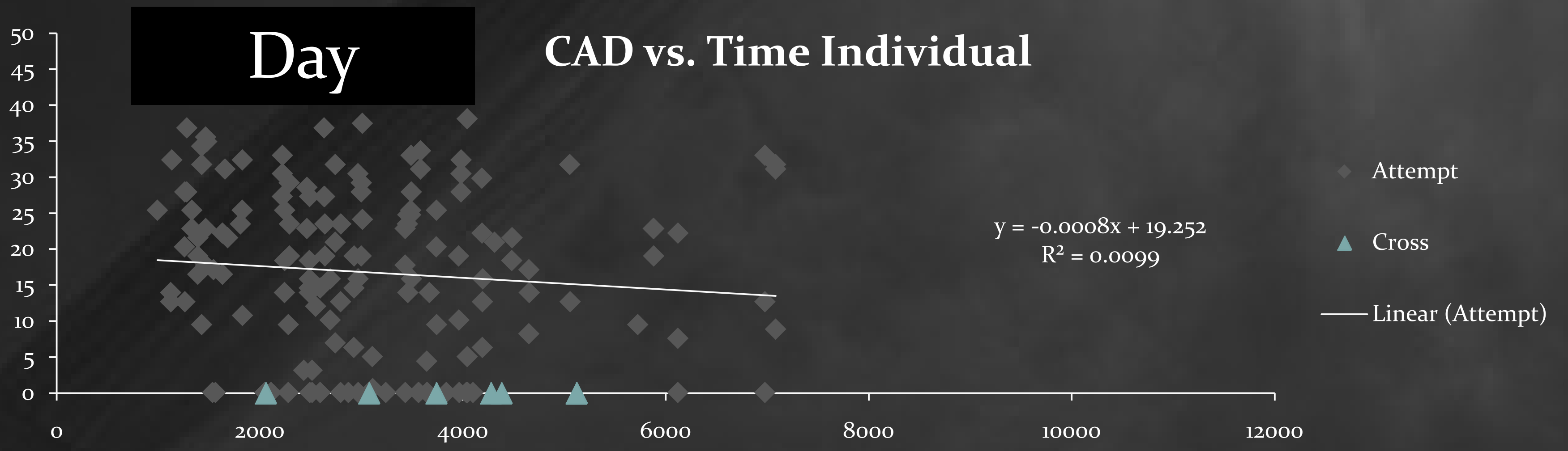
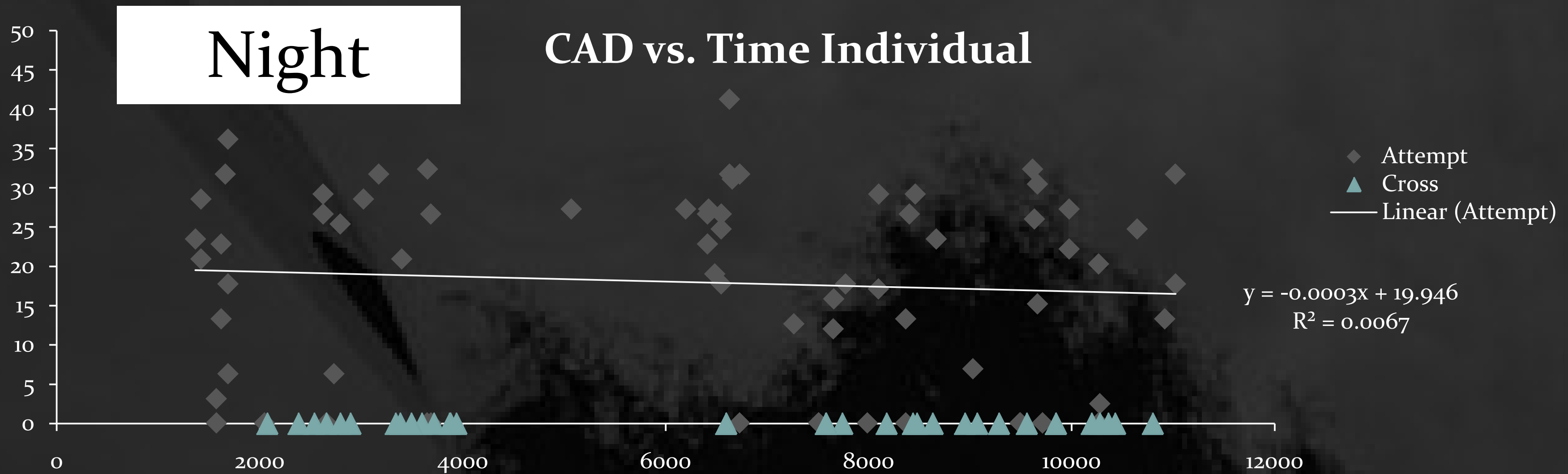
0-5
5.1-10
10.1-15
15.1-20
20.1-25
25.1-30
30.1-35
35.1-40
40.1-45
45.1-50
Distance (cm)
Cross
Attempt


Day
CAD vs. Time Individual
y = -0.0008x + 19.252
R² = 0.0099
Attempt
Cross
Linear (Attempt)
50
45
40
35
30
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000


Night
CAD vs. Time Individual
Attempt
Cross
Linear (Attempt)
y = -0.0003x + 19.946
R² = 0.0067
50
45
40
35
30
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000

Summary Table	Day_1	Day_2	Day_3	Night_1	Night_2	Night_3	Day_All	Night_All	All
T_0 (hh:mm:ss)	15:47:06	12:35:10	14:38:22	17:29:51	18:20:12	21:15:00	NA	NA	NA
Time to 1st Event (hh:mm:ss)	0:18:44	0:22:12	0:16:33	1:47:02	0:56:39	0:22:47	0:19:10	1:02:09	-
Group Events (n)	25	25	25	25	25	25	75	75	150
Individual Events (n')	58	60	45	34	34	36	163	104	267
% Shoaled	89.7	93.3	73.3	47.1	52.9	47.2	86.5	49.0	67.8
% Solitary*	10.3	6.7	26.7	52.9	47.1	52.8	13.5	51.0	32.2
Attempts	58	57	40	22	26	21	155	69	224
Median Ind. CAD (cm)	13.34	20.96	10.93	6.99	17.78	1.64	17.78	20.955	18.42
Crossings	0	3	5	12	8	15	8	35.0	43
% Parallel	NA	100.0	100.0	91.7	100.0	61.5	100.0	78.8	89.4
% Oblique/Jump	NA	0.0	0.0	8.3	0.0	38.5	0.0	21.2	10.6
% Upstream	NA	100.0	100.0	83.3	100.0	41.7	100.0	72.7	86.4
% Downstream	NA	0.0	0.0	16.7	0.0	58.3	0.0	27.3	13.6

Discussion

- Difference in day and night distributions / trial stats
  - More crossings at night
  - Lower frequency of events
  - More Shoaling in daylight
- Correlation of Median CAD and SPL fields
- Existence of many "touching barrier" CAD events
  - Bi-Modal Distribution
- In each trial, many attempt activity happened before the first cross
  - CAD vs Time plots

Conclusions

- Mechanism/s responsible for aversive response to bubble barriers is/are complicated.
  - Vision appears to have a limited role?
  - Audition appears to be mostly responsible.
  - Learning is key, but still not well understood
- Mutability of auditory sense probable
  - Explains “in barrier” distribution frequency.
- Qualitative observations and CAD vs. time plot suggest fast “learning curve” to bubble barrier scenario.
  - Exploratory behaviors observed.
  - Individual differences in the carp probably exist (Shy / Bold continuum).

References

- Zielinski, D. 2011. Bubble barrier technologies for common carp. M.S. University of Minnesota, St. Paul, Minnesota.