Effects of Flow Regulation on Anuran Occupancy and Abundance in Riparian Zones

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CABW/SFS Meeting – 11/19/2014

Davidson College
UC Davis - Graduate Group in Ecology

Global Boom in Dams Could Mean Biodiversity Bust, Scientists Warn

BY MIGUEL LLANOS

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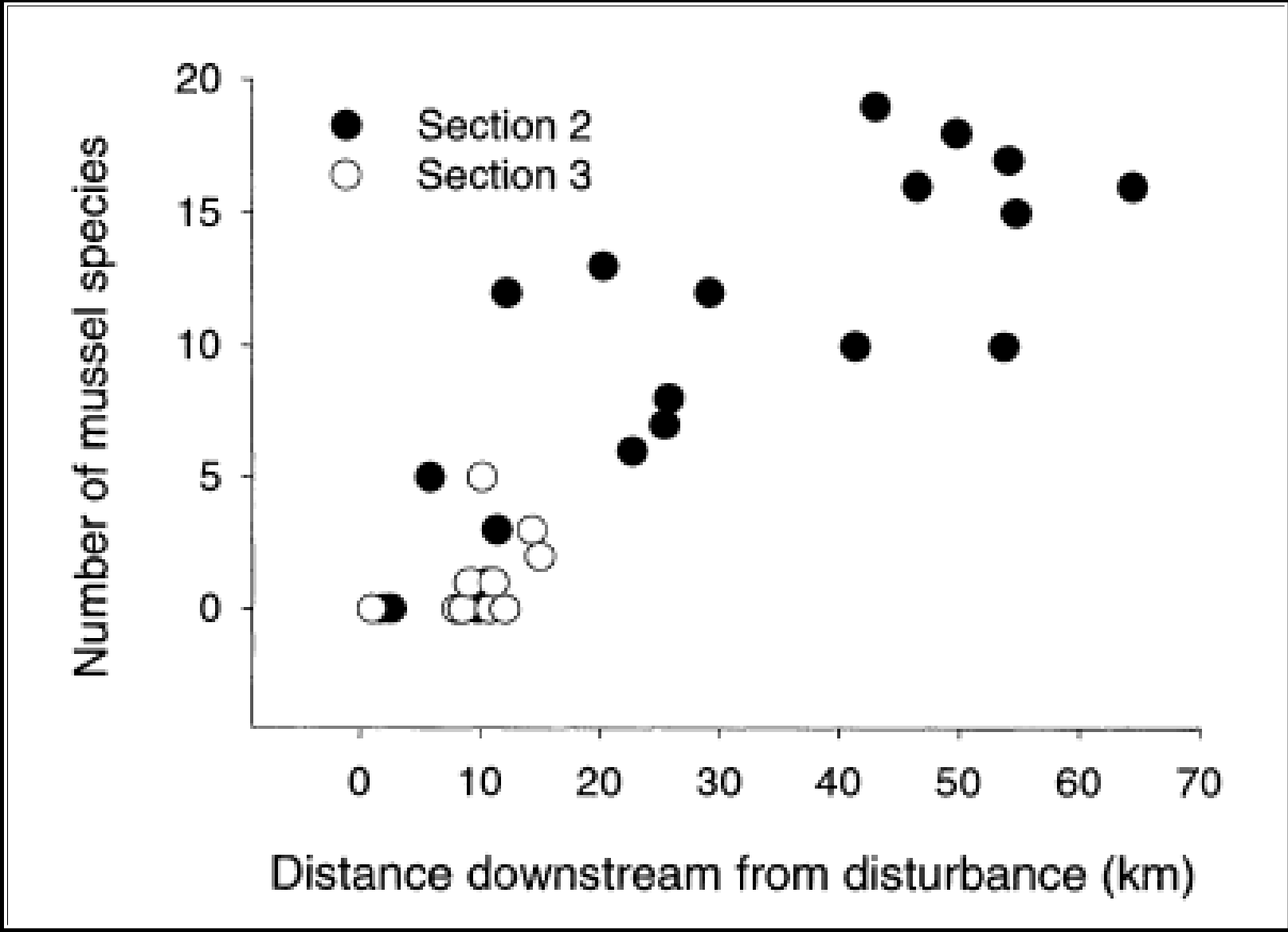
Flow Regulation Through Damming

Dispersal

Downstream Flows

Water Releases

Effects on Riverine Fauna



Anurans in Riparian Zones

Biphasic Life Cycle

Life History Variation

Urbanization

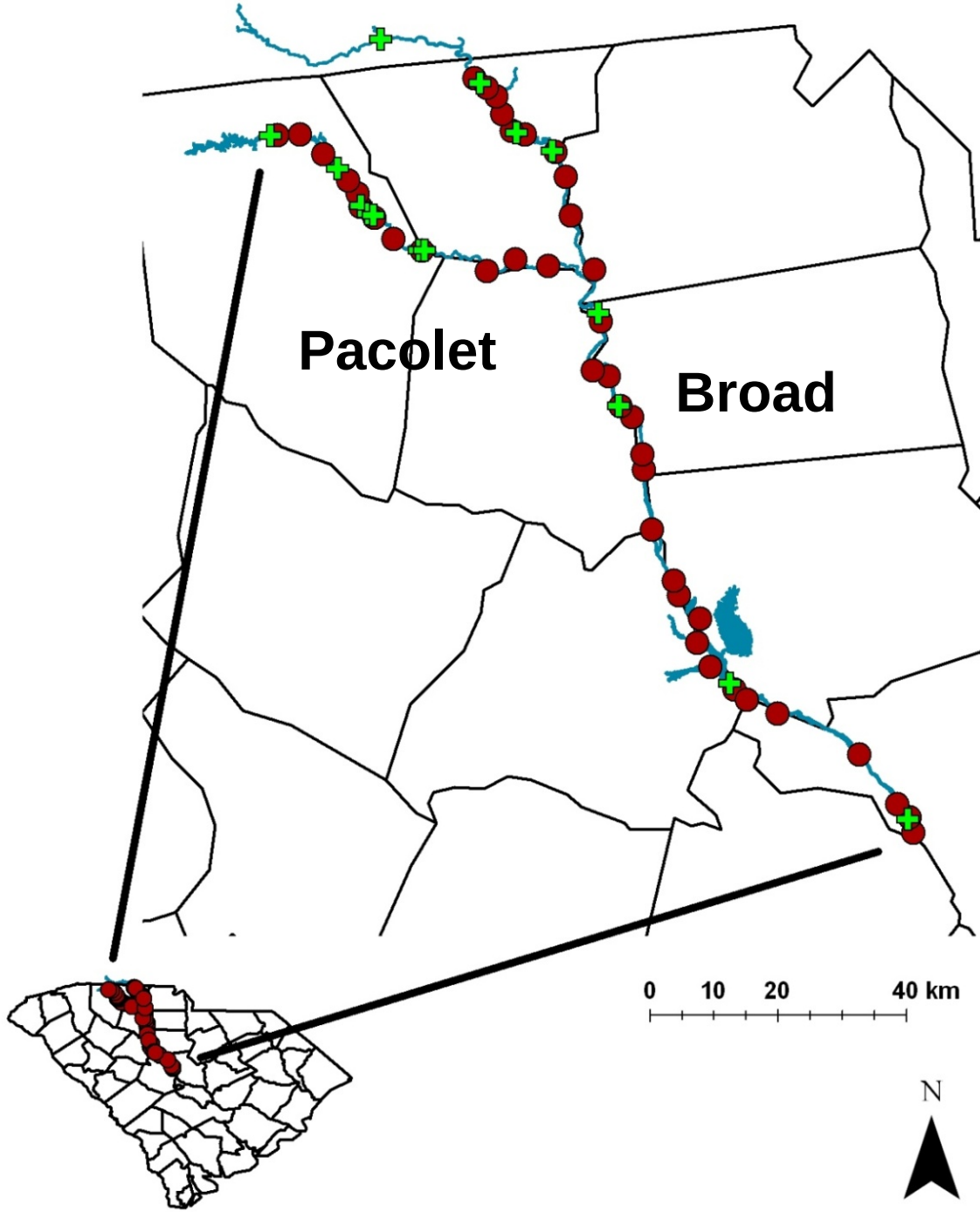
Objectives

To evaluate the effect of dam proximity on occupancy and abundance of anurans inhabiting riparian zones

To evaluate urbanization as an alternate stressor to riparian zone anurans

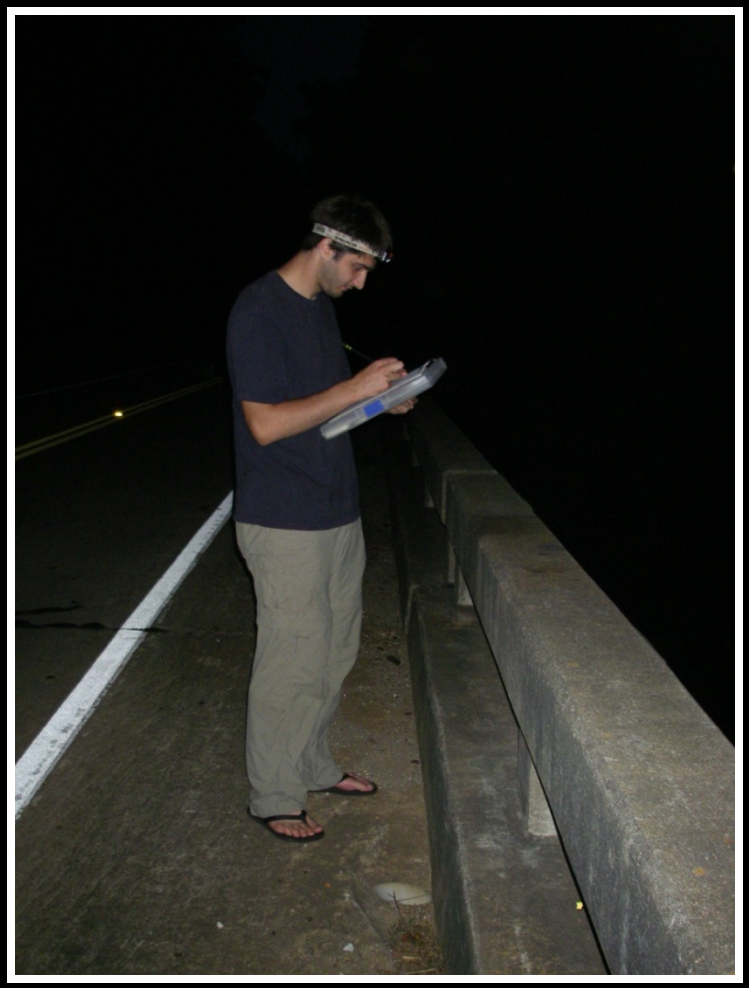
Methods

- 42 study sites
- 16 dams identified

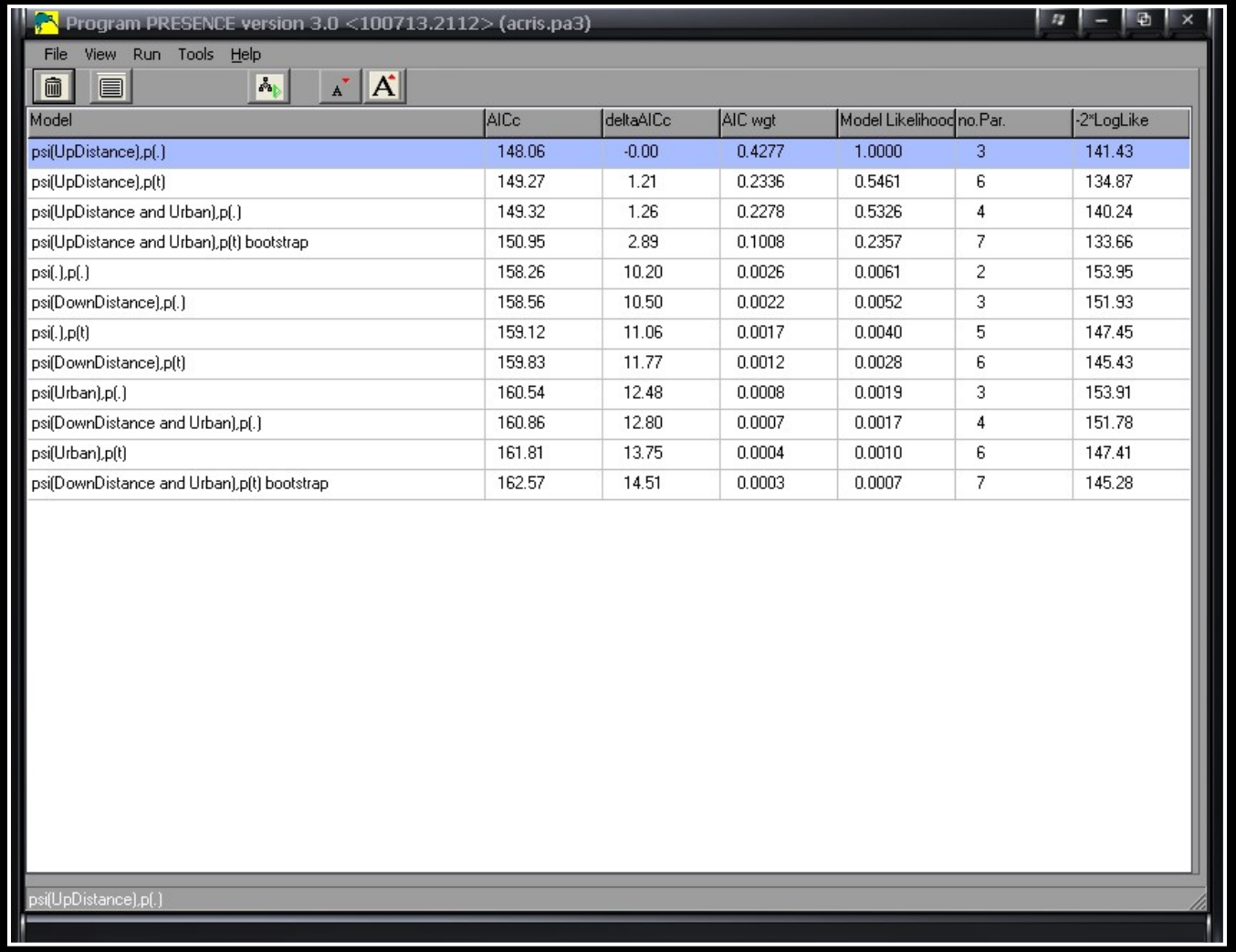


Methods – Data Collection

- Manual calling surveys
- Three calling windows
  - spring (April 13 – May 8)
  - summer (June 8 – 24)
  - winter (Feb 21 – Mar 24)
- Three surveys within each calling window



Methods – Data Analysis



Model	AICc	deltaAICc	AIC wgt	Model Likelihood	no.Par.	-2*LogLike
psi(UpDistance),p(.)	148.06	-0.00	0.4277	1.0000	3	141.43
psi(UpDistance),p(t)	149.27	1.21	0.2336	0.5461	6	134.87
psi(UpDistance and Urban),p(.)	149.32	1.26	0.2278	0.5326	4	140.24
psi(UpDistance and Urban),p(t) bootstrap	150.95	2.89	0.1008	0.2357	7	133.66
psi(.),p(.)	158.26	10.20	0.0026	0.0061	2	153.95
psi(DownDistance),p(.)	158.56	10.50	0.0022	0.0052	3	151.93
psi(.),p(t)	159.12	11.06	0.0017	0.0040	5	147.45
psi(DownDistance),p(t)	159.83	11.77	0.0012	0.0028	6	145.43
psi(Urban),p(.)	160.54	12.48	0.0008	0.0019	3	153.91
psi(DownDistance and Urban),p(.)	160.86	12.80	0.0007	0.0017	4	151.78
psi(Urban),p(t)	161.81	13.75	0.0004	0.0010	6	147.41
psi(DownDistance and Urban),p(t) bootstrap	162.57	14.51	0.0003	0.0007	7	145.28

Results

Table 1. Summary data for nine anuran species recorded during calling surveys.

Species	No. of Surveys Used in Final Analysis	Naïve Occupancy
Cricket Frog	4	0.43
American Toad	3	0.52
Fowler’s Toad	6	0.95
Cope’s Gray Treefrog	5	0.79
Spring Peeper	6	0.76
Upland Chorus Frog	3	0.76
Bullfrog	5	0.43
Green Frog	5	0.43
Southern Leopard Frog	3	0.33

Results

Table 2. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of cricket frogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
Ψ(DownFromDam), p(.)	141.43	3	148.06	0	0.4277
Ψ(DownFromDam), p(t)	134.87	6	149.27	1.21	0.2336
Ψ(DownFromDam and Urban), p(.)	140.24	4	149.32	1.26	0.2278
Ψ(DownFromDam and Urban), p(t)	133.66	7	150.95	2.89	0.1008
Ψ(.), p(.)	153.95	2	158.26	10.20	0.0026
Ψ(UpFromDam), p(.)	151.93	3	158.56	10.50	0.0022
Ψ(.), p(t)	147.45	5	159.12	11.06	0.0017
Ψ(UpFromDam), p(t)	145.43	6	159.83	11.77	0.0012
Ψ(Urban), p(.)	153.91	3	160.54	12.48	0.0008
Ψ(UpFromDam and Urban), p(.)	151.78	4	160.86	12.80	0.0007
Ψ(Urban), p(t)	147.41	6	161.81	13.75	0.0004
Ψ(UpFromDam and Urban), p(t)	145.28	7	162.57	14.51	0.0003

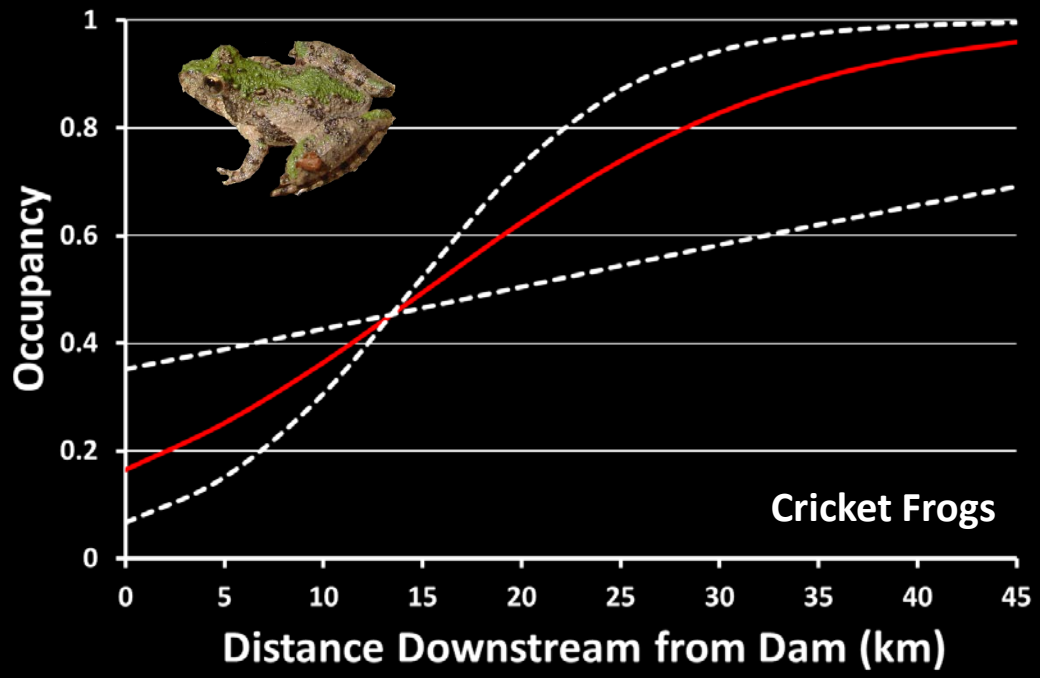
Ψ = occupancy parameter; *p* = detection parameter

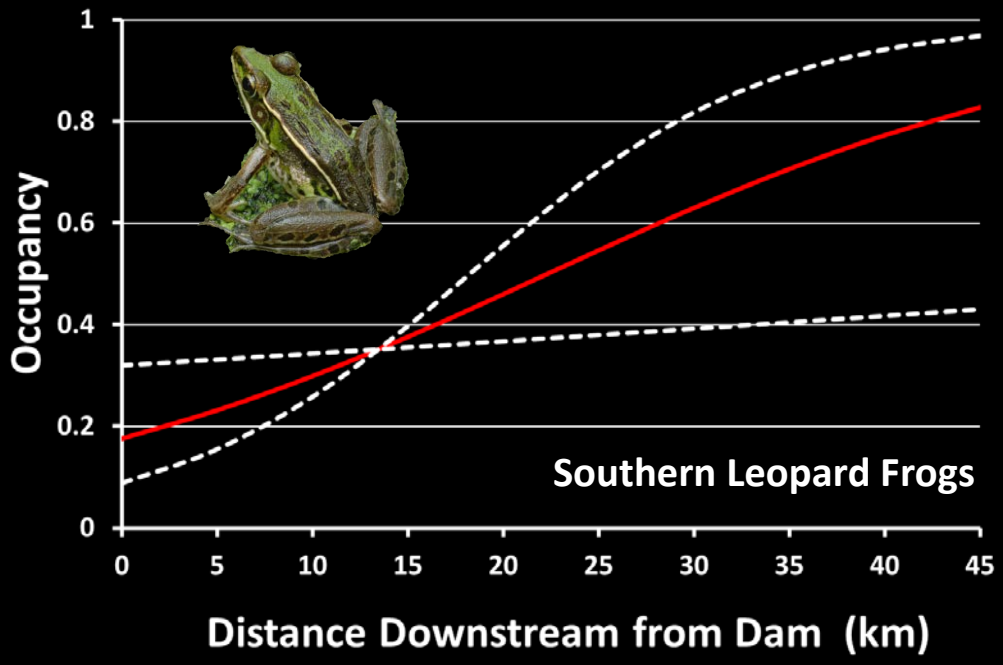
Results

Table 3. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of cricket frogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(DownFromDam)	138.57	3	145.20	0	0.9940
λ(UpFromDam)	150.03	3	156.66	11.46	0.0032
λ(.)	153.19	2	157.50	12.30	0.0021
λ(Urban)	153.19	3	159.82	14.62	0.0007

λ = abundance parameter


Occupancy
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
Distance Downstream from Dam (km)
Cricket Frogs


Occupancy
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
Distance Downstream from Dam (km)
Southern Leopard Frogs

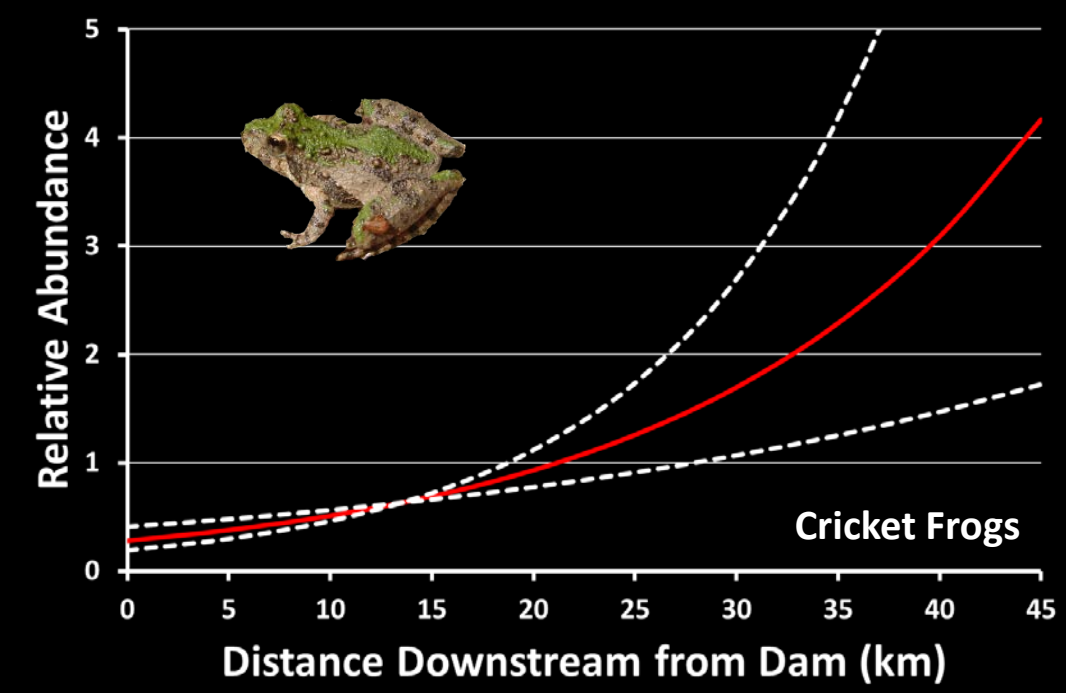
Bullfrogs

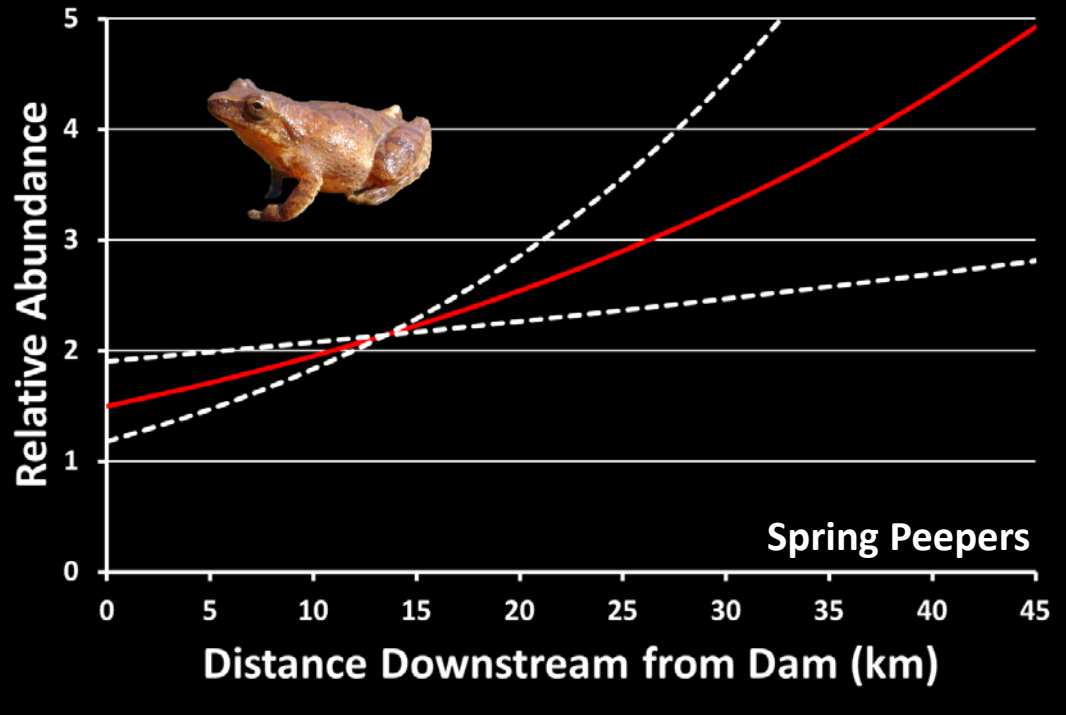
Occupancy

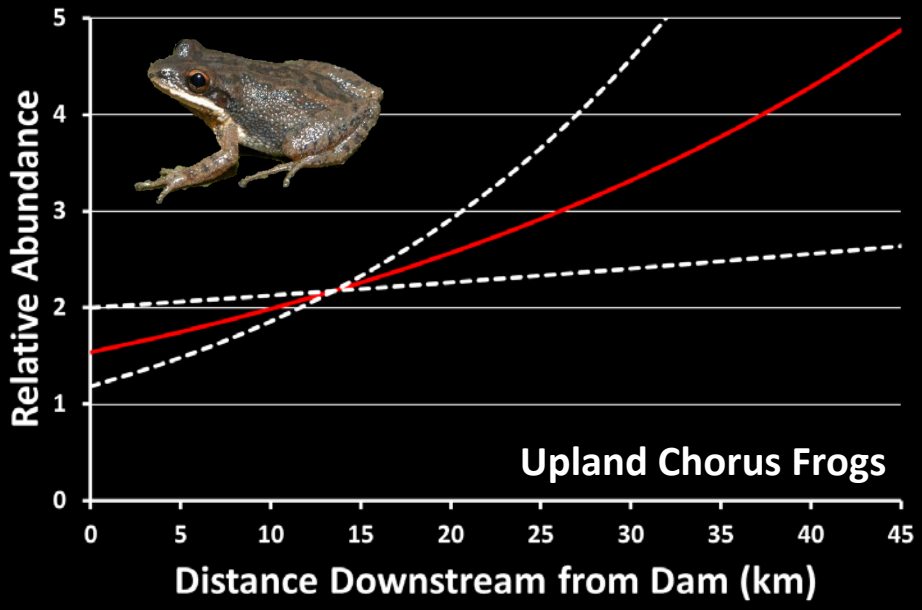
1
0.8
0.6
0.4
0.2
0

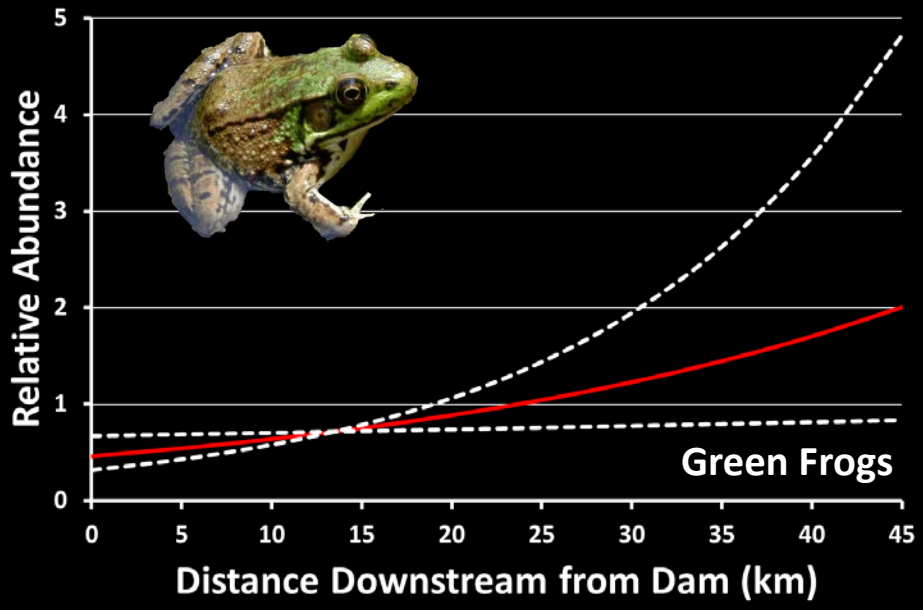
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45

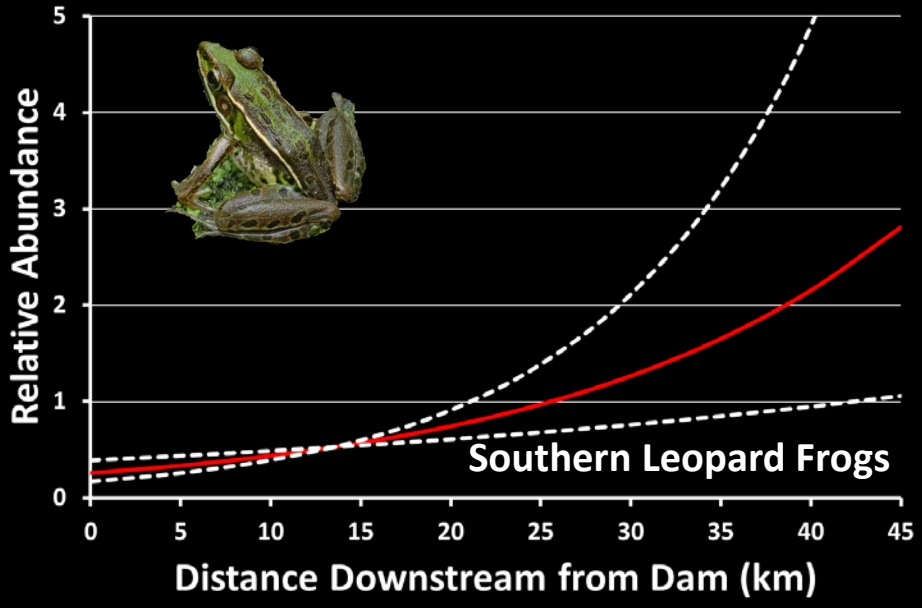
Percent Urban Cover in Buffer Zone


Relative Abundance
0
1
2
3
4
5
0
5
10
15
20
25
30
35
40
45
Distance Downstream from Dam (km)
Cricket Frogs


Relative Abundance
0
1
2
3
4
5
0
5
10
15
20
25
30
35
40
45
Distance Downstream from Dam (km)
Spring Peepers


Relative Abundance
0
1
2
3
4
5
0
5
10
15
20
25
30
35
40
45
Distance Downstream from Dam (km)
Upland Chorus Frogs


Relative Abundance
0
1
2
3
4
5
0
5
10
15
20
25
30
35
40
45
Distance Downstream from Dam (km)
Green Frogs


Relative Abundance
0
1
2
3
4
5
0
5
10
15
20
25
30
35
40
45
Distance Downstream from Dam (km)
Southern Leopard Frogs

Fowler's Toad

Relative Abundance

20
16
12
8
4
0

0 5 10 15 20 25 30 35 40 45

Distance Downstream from Dam (km)

Bullfrogs

Relative Abundance

2
1.5
1
0.5
0

0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45

Percent Urban Cover in Buffer Zone

Summary and Conclusions

- Downstream distance impacts greater than upstream distance
- Distance downstream positively correlated with population metrics
- Urbanization

Discussion - Mechanisms

- Reduced flows and flooding events
  - Reduced riparian wetland habitat
- Temporal changes in flow regime
- Water release events

Implications and Future Directions

- Riparian zone fauna
- Dam removal or other mitigation
- Mechanisms

Conservation Biology

Contributed Paper

Effects of River-Flow Regulation on Anuran Occupancy and Abundance in Riparian Zones

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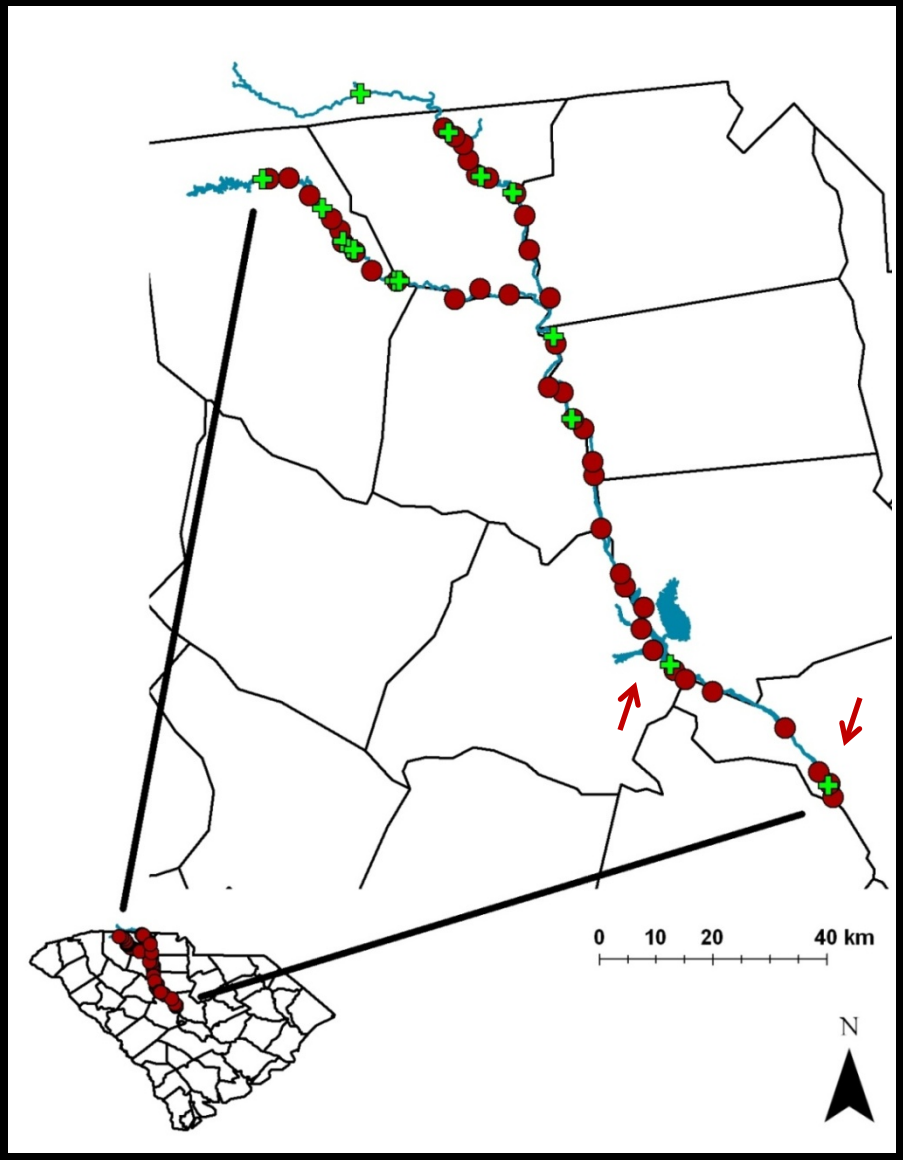
Thank You

Summary of Dam Operational Types

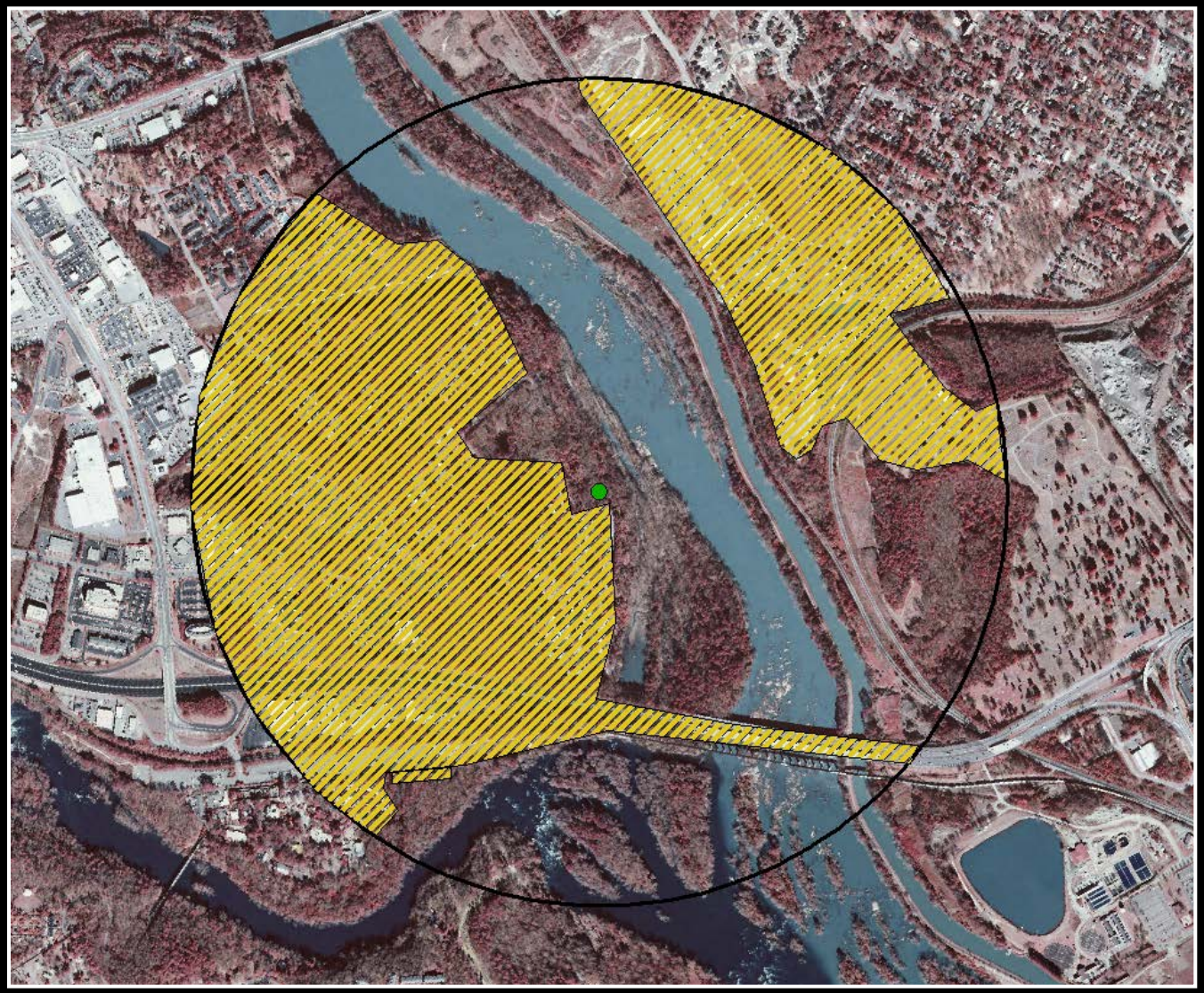
- 7 dams used for generation of hydroelectric power
- 2 dams impound reservoirs that provide water sources
- 1 dam used for cooling of coal plant machinery
- 6 historic mill dams

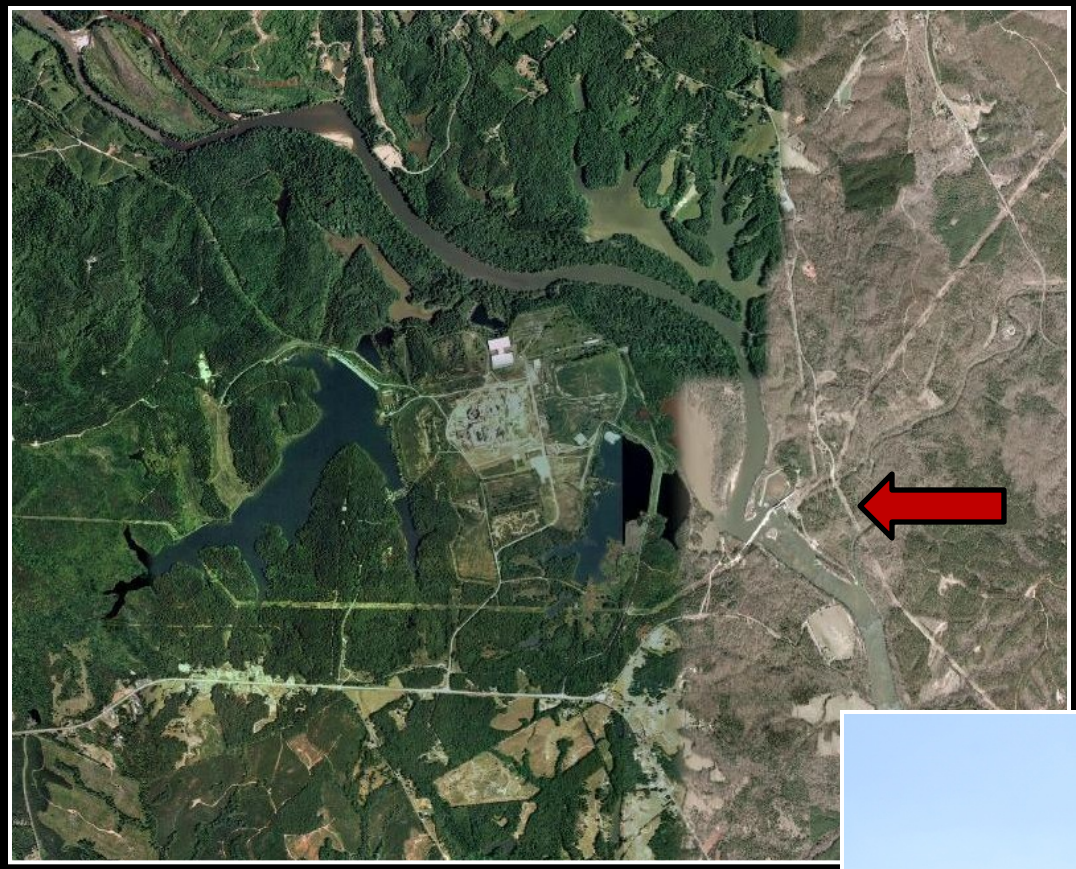
Fowler's Toads



Methods – Urban Land Cover

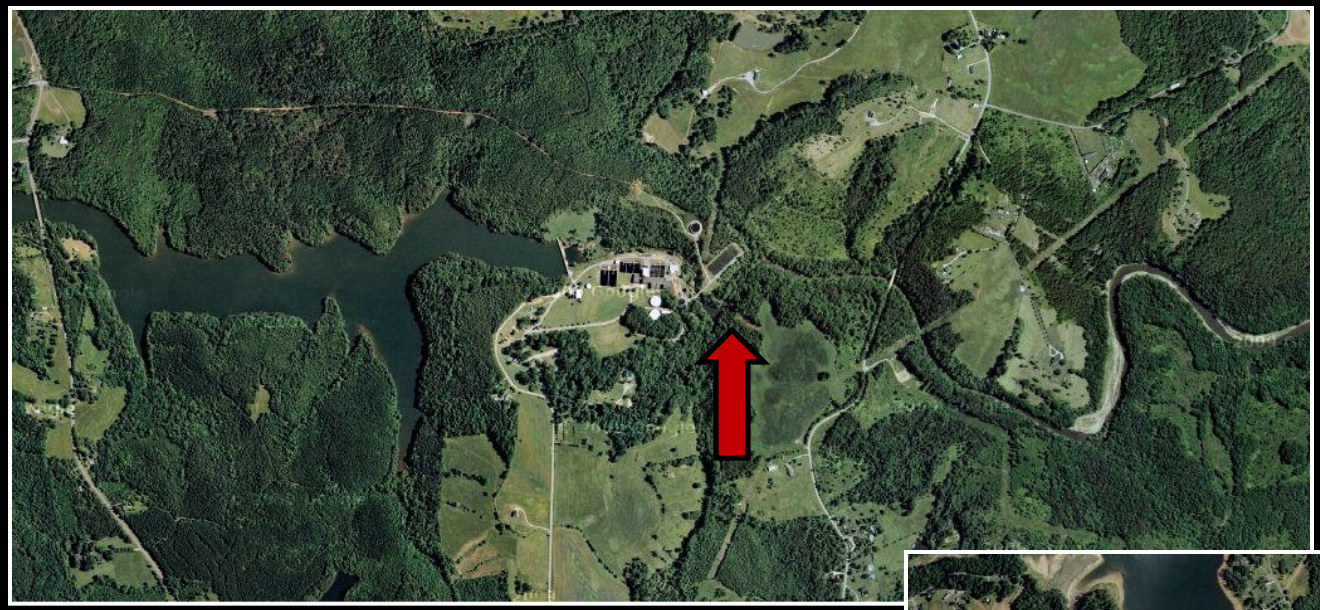
Methods – Urban Land Cover

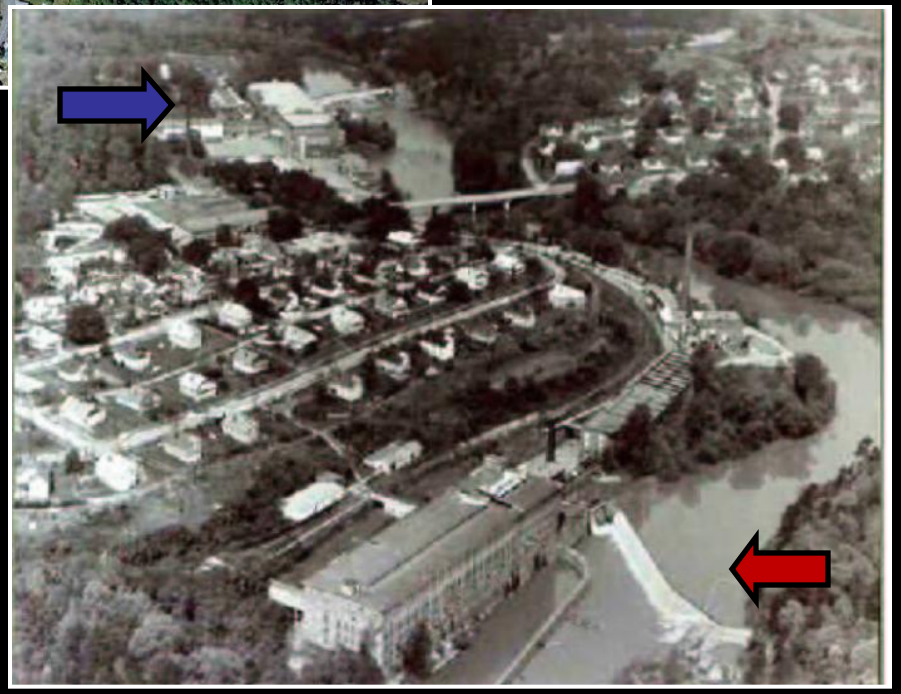




Hydroelectric Power

Water Sources





Mill Dams

http://pacoletmemories.com/millcompany.html

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of American toads.

Model	$-2\log_e L$	No. Parameters	$QAIC_c$	$\Delta QAIC_c$	*w*
Ψ(Urban), p(.)	138.72	3	132.72	0	0.2507
Ψ(.), p(.)	141.56	2	132.98	0.26	0.2201
Ψ(UpFromDam and Urban), p(.)	137.48	4	134.04	1.32	0.1296
Ψ(DownFromDam and Urban), p(.)	138.39	4	134.87	2.15	0.0855
Ψ(UpFromDam), p(.)	141.37	3	135.13	2.41	0.0751
Ψ(DownFromDam), p(.)	141.55	3	135.29	2.57	0.0693
Ψ(.), p(t)	139.51	4	135.89	3.17	0.0514
Ψ(Urban), p(t)	136.70	5	135.92	3.20	0.0506
Ψ(UpFromDam and Urban), p(t)	135.42	6	137.49	4.77	0.0231
Ψ(UpFromDam), p(t)	139.31	5	138.29	5.57	0.0155
Ψ(DownFromDam and Urban), p(t)	136.39	6	138.37	5.65	0.0149
Ψ(DownFromDam), p(t)	139.49	5	138.45	5.73	0.0143

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of Cope's gray treefrogs.

Model	$-2\log_e L$	No. Parameters	$QAIC_c$	$\Delta QAIC_c$	*w*
Ψ(.), p(t)	243.09	6	158.72	0	0.2274
Ψ(.), p(.)	260.51	2	158.97	0.25	0.2007
Ψ(UpFromDam), p(.)	259.49	3	160.69	1.97	0.0849
Ψ(Urban), p(.)	259.66	3	160.79	2.07	0.0808
Ψ(DownFromDam), p(.)	259.90	3	160.93	2.21	0.0753
Ψ(UpFromDam), p(t)	241.96	7	160.94	2.22	0.0749
Ψ(Urban), p(t)	242.32	7	161.16	2.44	0.0671
Ψ(DownFromDam), p(t)	242.45	7	161.23	2.51	0.0648
Ψ(UpFromDam and Urban), p(.)	257.44	4	161.92	3.20	0.0459
Ψ(UpFromDam and Urban), p(t)	239.89	8	162.78	4.06	0.0299
Ψ(DownFromDam and Urban), p(.)	258.92	4	162.80	4.08	0.0296
Ψ(DownFromDam and Urban), p(t)	241.49	8	163.73	5.01	0.0186

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of green treefrogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
Ψ(DownFromDam), p(.)	165.15	3	171.78	0	0.5728
Ψ(DownFromDam and Urban), p(.)	165.10	4	174.18	2.40	0.1725
Ψ(.), p(.)	170.91	2	175.22	3.44	0.1026
Ψ(DownFromDam), p(t)	162.34	6	176.74	4.96	0.0480
Ψ(Urban), p(.)	170.85	3	177.48	5.70	0.0331
Ψ(UpFromDam), p(.)	170.86	3	177.49	5.71	0.0330
Ψ(DownFromDam and Urban), p(t)	162.29	7	179.58	7.80	0.0116
Ψ(.), p(t)	168.12	5	179.79	8.01	0.0104
Ψ(UpFromDam and Urban), p(.)	170.83	4	179.91	8.13	0.0098
Ψ(Urban), p(t)	168.06	6	182.46	10.68	0.0027
Ψ(UpFromDam), p(t)	168.06	6	182.46	10.68	0.0027
Ψ(UpFromDam and Urban), p(t)	168.04	7	185.33	13.55	0.0007

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of spring peepers.

Model	$-2\log_e L$	No. Parameters	$QAIC_c$	$\Delta QAIC_c$	*w*
Ψ(DownFromDam and Urban), p(t)	248.72	9	198.98	0	0.3463
Ψ(.), p(t)	258.43	7	199.49	0.51	0.2684
Ψ(DownFromDam), p(t)	254.60	8	199.86	0.88	0.2231
Ψ(UpFromDam), p(t)	257.55	8	201.94	2.96	0.0788
Ψ(Urban), p(t)	257.99	8	202.25	3.27	0.0675
Ψ(UpFromDam and Urban), p(t)	257.48	9	205.15	6.17	0.0158
Ψ(DownFromDam and Urban), p(.)	297.24	4	218.64	19.66	0.0000
Ψ(DownFromDam), p(.)	303.78	3	220.80	21.82	0.0000
Ψ(.), p(.)	309.18	2	222.29	23.31	0.0000
Ψ(UpFromDam), p(.)	308.30	3	223.99	25.01	0.0000
Ψ(Urban), p(.)	308.70	3	224.27	25.29	0.0000
Ψ(UpFromDam and Urban), p(.)	308.23	4	226.39	27.41	0.0000

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of upland chorus frogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
Ψ(DownFromDam), p(t)	151.32	5	162.99	0	0.3685
Ψ(DownFromDam), p(.)	156.51	3	163.14	0.15	0.3418
Ψ(DownFromDam and Urban), p(.)	156.32	4	165.40	2.41	0.1104
Ψ(DownFromDam and Urban), p(t)	151.02	6	165.42	2.43	0.1093
Ψ(.), p(t)	160.16	4	169.24	6.25	0.0162
Ψ(Urban), p(t)	158.00	5	169.67	6.68	0.0131
Ψ(.), p(.)	165.55	2	169.86	6.87	0.0119
Ψ(Urban), p(.)	163.37	3	170.00	7.01	0.0111
Ψ(UpFromDam and Urban), p(t)	157.26	6	171.66	8.67	0.0048
Ψ(UpFromDam and Urban), p(.)	162.64	4	171.72	8.73	0.0047
Ψ(UpFromDam), p(t)	160.14	5	171.81	8.82	0.0045
Ψ(UpFromDam), p(.)	165.52	3	172.15	9.16	0.0038

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of bullfrogs.

Model	$-2\log_e L$	No. Parameters	$QAIC_c$	$\Delta QAIC_c$	*w*
Ψ(Urban), p(.)	170.64	3	112.34	0	0.5024
Ψ(UpFromDam and Urban), p(.)	169.95	4	114.36	2.02	0.1830
Ψ(DownFromDam and Urban), p(.)	170.62	4	114.77	2.43	0.1491
Ψ(.), p(.)	179.95	2	115.78	3.44	0.0900
Ψ(UpFromDam), p(.)	179.59	3	117.88	5.54	0.0315
Ψ(DownFromDam), p(.)	179.74	3	117.97	5.63	0.0301
Ψ(Urban), p(t)	166.94	7	120.71	8.37	0.0076
Ψ(UpFromDam and Urban), p(t)	166.25	8	123.35	11.01	0.0020
Ψ(.), p(t)	176.25	6	123.58	11.24	0.0018
Ψ(DownFromDam and Urban), p(t)	166.93	8	123.77	11.43	0.0017
Ψ(UpFromDam), p(t)	175.89	7	126.25	13.91	0.0005
Ψ(DownFromDam), p(t)	176.04	7	126.34	14.00	0.0005

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of green frogs.

Model	$-2\log_e L$	No. Parameters	$QAIC_c$	$\Delta QAIC_c$	*w*
Ψ(.), p(t)	152.93	6	147.06	0	0.3991
Ψ(DownFromDam), p(t)	150.45	7	147.80	0.74	0.2757
Ψ(UpFromDam), p(t)	152.46	7	149.55	2.49	0.1149
Ψ(Urban), p(t)	152.62	7	149.68	2.62	0.1077
Ψ(DownFromDam and Urban), p(t)	150.37	8	150.80	3.74	0.0615
Ψ(UpFromDam and Urban), p(t)	151.61	8	151.88	4.82	0.0358
Ψ(.), p(.)	177.15	2	157.98	10.92	0.0017
Ψ(DownFromDam), p(.)	174.59	3	158.08	11.02	0.0016
Ψ(UpFromDam), p(.)	176.67	3	159.88	12.82	0.0007
Ψ(Urban), p(.)	176.83	3	160.02	12.96	0.0006
Ψ(DownFromDam and Urban), p(.)	174.53	4	160.48	13.42	0.0005
Ψ(UpFromDam and Urban), p(.)	175.82	4	161.60	14.54	0.0003

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on occupancy of southern leopard frogs.

Model	$-2\log_e L$	No. Parameters	$QAIC_c$	$\Delta QAIC_c$	*w*
Ψ(DownFromDam), p(.)	101.01	3	67.73	0	0.3245
Ψ(.), p(.)	107.81	2	69.52	1.79	0.1326
Ψ(DownFromDam), p(t)	95.93	5	69.70	1.97	0.1212
Ψ(DownFromDam and Urban), p(.)	100.28	4	69.74	2.01	0.1188
Ψ(Urban), p(.)	106.32	3	70.95	3.22	0.0649
Ψ(.), p(t)	102.80	4	71.27	3.54	0.0553
Ψ(UpFromDam), p(.)	107.08	3	71.41	3.68	0.0515
Ψ(DownFromDam and Urban), p(t)	95.19	6	71.98	4.25	0.0388
Ψ(UpFromDam and Urban), p(.)	104.06	4	72.03	4.30	0.0378
Ψ(Urban), p(t)	101.31	5	72.95	5.22	0.0239
Ψ(UpFromDam), p(t)	102.07	5	73.41	5.68	0.0190
Ψ(UpFromDam and Urban), p(t)	99.07	6	74.33	6.60	0.0120

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of American toads.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(.)	142.11	2	146.42	0	0.4149
λ(Urban)	140.46	3	147.09	0.67	0.2968
λ(DownFromDam)	141.89	3	148.52	2.10	0.1452
λ(UpFromDam)	141.92	3	148.55	2.13	0.1430

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of Fowler's toads.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(DownFromDam)	323.55	3	330.18	0	0.9909
λ(.)	336.34	2	340.65	10.47	0.0053
λ(UpFromDam)	335.94	3	342.57	12.39	0.0020
λ(Urban)	336.14	3	342.77	12.59	0.0018

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of Cope's gray treefrogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(.)	258.76	2	263.07	0	0.4208
λ(Urban)	257.24	3	263.87	0.80	0.2821
λ(DownFromDam)	258.43	3	265.06	1.99	0.1556
λ(UpFromDam)	258.62	3	265.25	2.18	0.1415

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of green treefrogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(DownFromDam)	160.52	3	167.15	0	0.9757
λ(.)	171.24	2	175.55	8.40	0.0146
λ(Urban)	171.13	3	177.76	10.61	0.0048
λ(UpFromDam)	171.15	3	177.78	10.63	0.0048

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of spring peepers.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(DownFromDam)	294.62	3	301.25	0	0.8067
λ(UpFromDam)	298.85	3	305.48	4.23	0.0973
λ(.)	301.75	2	306.06	4.81	0.0728
λ(Urban)	301.72	3	308.35	7.10	0.0232

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of upland chorus frogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(DownFromDam)	159.82	3	166.45	0	0.6082
λ(Urban)	161.54	3	168.17	1.72	0.2574
λ(.)	165.71	2	170.02	3.57	0.1021
λ(UpFromDam)	165.69	3	172.32	5.87	0.0323

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of bullfrogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(Urban)	167.84	3	174.47	0	0.9447
λ(.)	177.10	2	181.41	6.94	0.0294
λ(DownFromDam)	176.01	3	182.64	8.17	0.0159
λ(UpFromDam)	176.94	3	183.57	9.10	0.0100

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of green frogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(DownFromDam)	169.86	3	176.49	0	0.6304
λ(.)	174.50	2	178.81	2.32	0.1976
λ(UpFromDam)	173.55	3	180.18	3.69	0.0996
λ(Urban)	174.19	3	180.82	4.33	0.0723

Results

Table. PRESENCE model set analyzing the effects of distance upstream and downstream to nearest dam and urbanization level on abundance of southern leopard frogs.

Model	$-2\log_e L$	No. Parameters	AIC_c	ΔAIC_c	*w*
λ(DownFromDam)	97.50	3	104.13	0	0.9425
λ(.)	106.97	2	111.28	7.15	0.0264
λ(UpFromDam)	105.41	3	112.04	7.91	0.0181
λ(Urban)	106.06	3	112.69	8.56	0.0130