Response of arid river fish assemblages to environmental flow regulation

Acknowledgements

- Collaborators: David Propst, Dale Ryden, and numerous others
- Funding: New Mexico Department of Game and Fish, U.S. Bureau of Reclamation (San Juan River Recovery and Implementation Program, SJRIP)
- Permits: New Mexico Department of Game and Fish, Navajo Nation, U.S. Fish and Wildlife Service

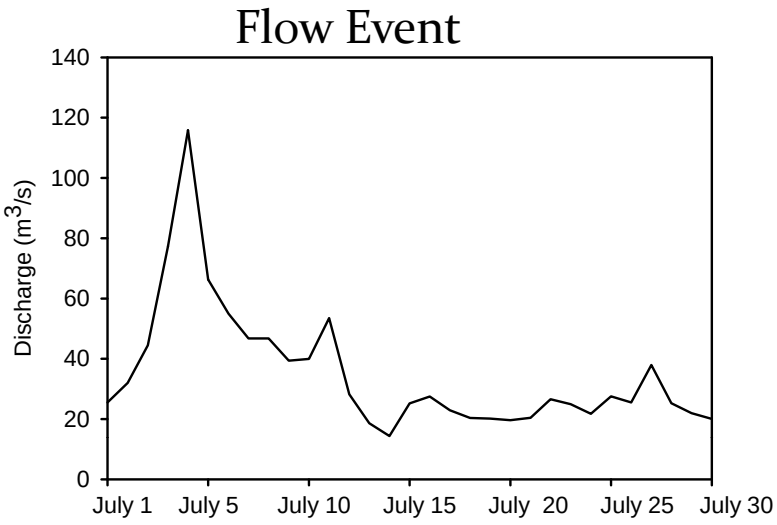
Outline

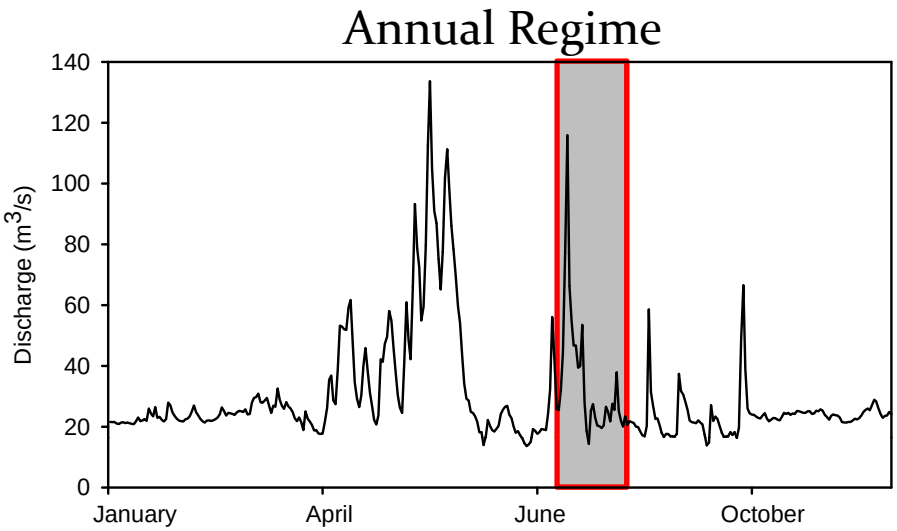
- Approach to characterizing biological response to flows
- Background San Juan River Program
- Long-term effects of flow attributes on fish assemblages in San Juan River
- General management considerations

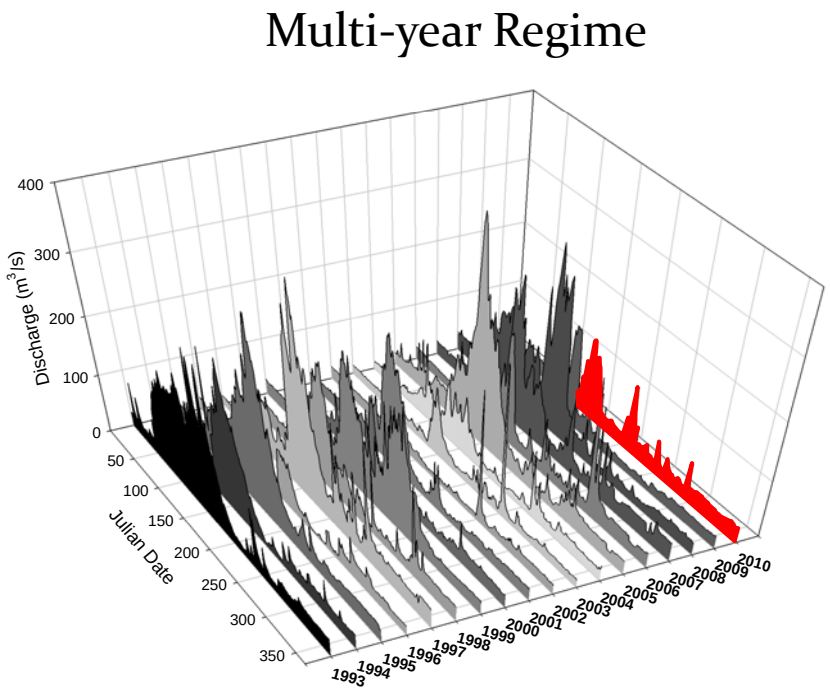
General approach to characterizing biological response to flow regulation

1) Ecosystem- or species based focus?
   - E.g., Poff et al. (1997) is ecosystem based
   - Management often driven by few species of concern
   - Natural flow restoration may (Bunn and Arthington 2002) or may not (Saunders and Tyus 1998) account for impacts by nonnative species
2) Characterize key flow regime attributes
3) Identify mechanistic pathways in which aspects of a flow regime influence key ecosystem processes or species of concern
   - Highlight pathways that can be manipulated by managers
4) Evaluate correlative data or conduct flow experiments

Characterizing key flow regime attributes





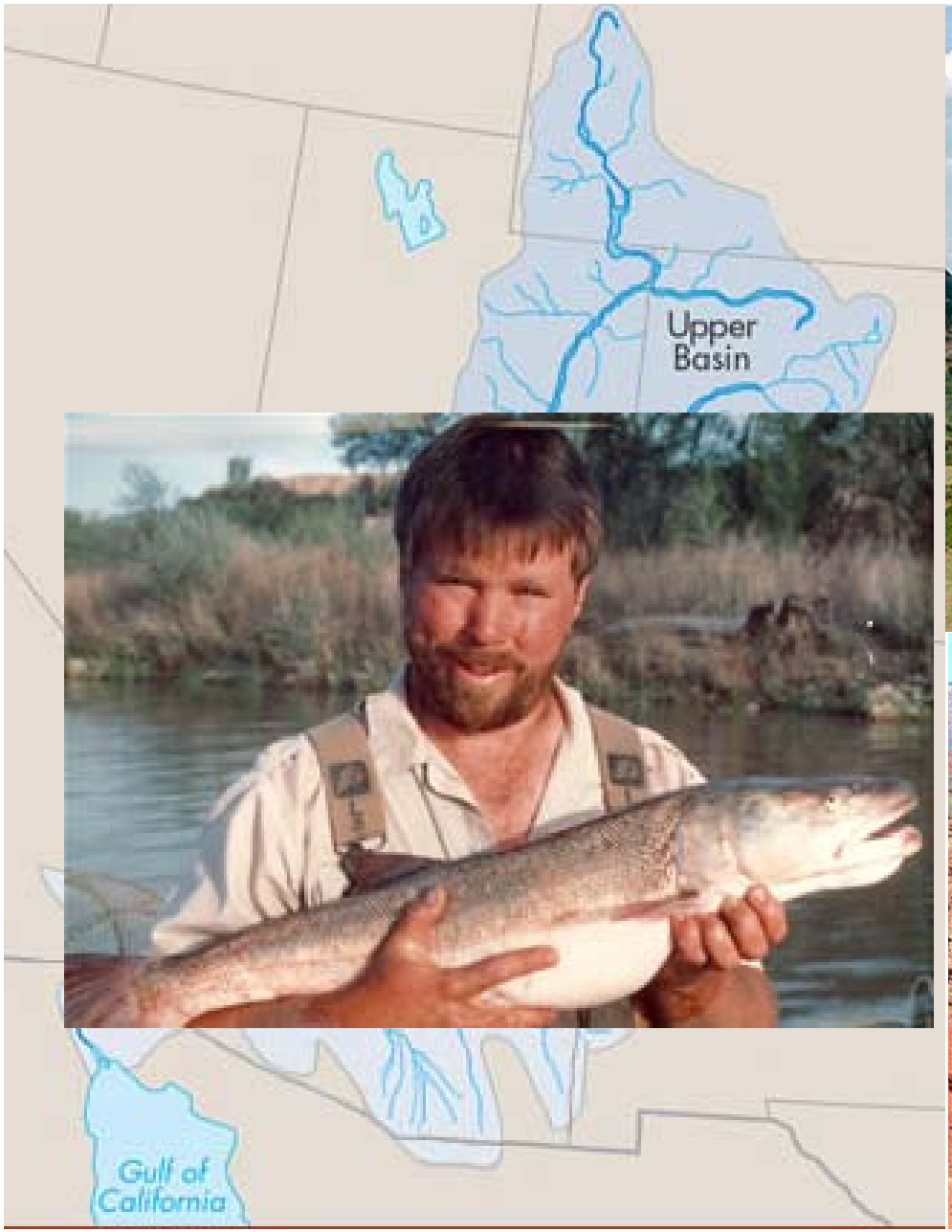


Characterizing response of biota to flows

Hydrologic time scale	Flow attributes (independent variables)	Biotic Response (dependent variables)
Flow Event	Magnitude, duration, rate of change	Scour, mortality, movement, etc.
Annual Regime	Flood frequency, mean flows, timing	Recruitment, community structure, etc.
Multi-year Regime	Annual attributes plus time lags	Population cycles, species persistence

- Spatial scale
  - Capture relevant ecological gradients (longitudinal zonation, tributary influences, etc.)

San Juan River



San Juan River Basin Recovery and Implementation Program

- Goals of the Program:
  - Conserve populations of the Colorado pikeminnow and razorback sucker (species-specific management)
  - Proceed with water development in the Basin
- 1993 – 1999 – Research phase
  - Biology committee commented on water allocation
  - Determine flow needs of endangered fishes
- 1999 – present – Recovery and implementation phase
  - Mimic natural flow regime (ecosystem based management) during spring snowmelt
  - Re-establish and augment populations on threatened species
  - Intensive nonnative removal

Other Fishes in the San Juan River

Natives

Flannelmouth Sucker

Bluehead Sucker

Speckled dace

Nonnative competitors

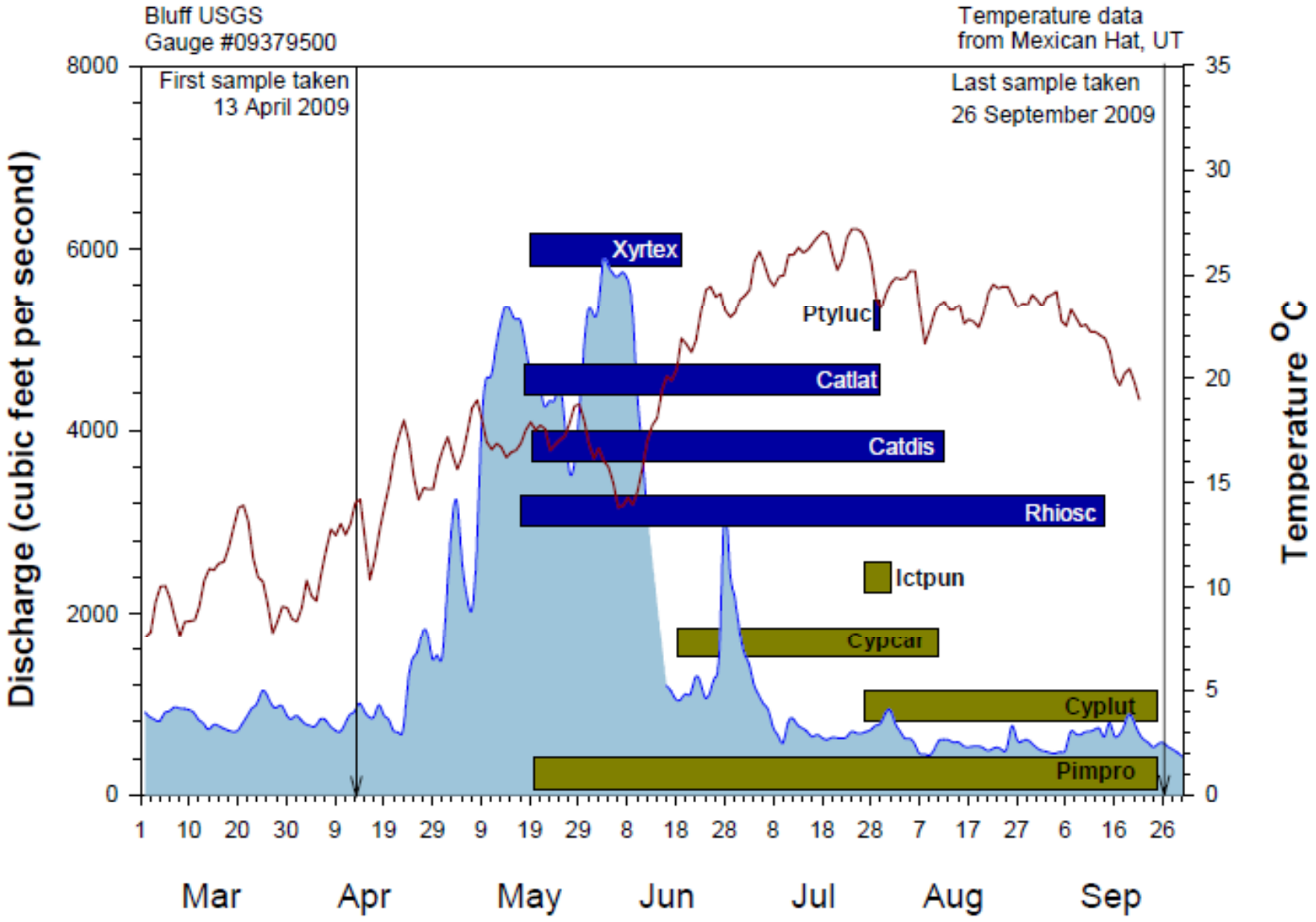
Fathead minnow

Red shiner

Nonnative predator

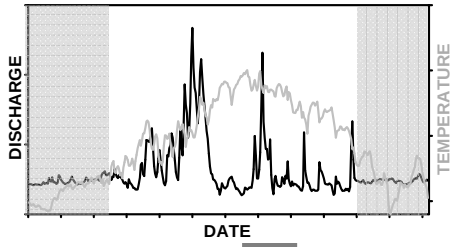
Channel catfish

Reproductive Ecology of Native and Nonnative Fishes



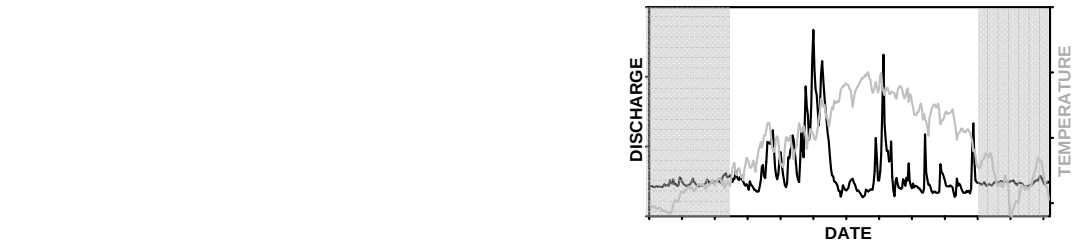
W. Howard Brandenburg and Michael A. Farrington (unpublished data)

Mechanistic pathway of factors influencing native fish recruitment



Pre-winter growth
<u>Winter maintenance</u>
•Stable flows
•Minimal biotic interactions

Mechanistic pathway of factors influencing native fish recruitment



Pre-winter growth
<u>Winter maintenance</u>
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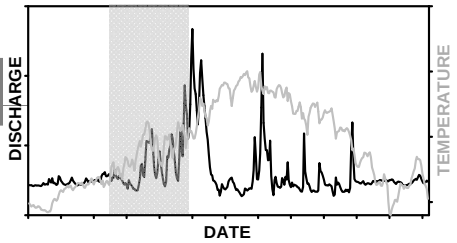
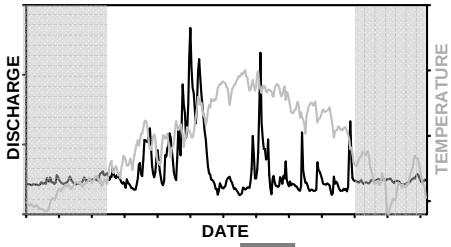
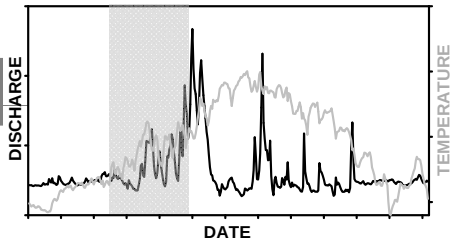
<u>Spring ovary development</u>
•Timing, magnitude and duration of spring runoff
•Temperature
•Minimal biotic interactions



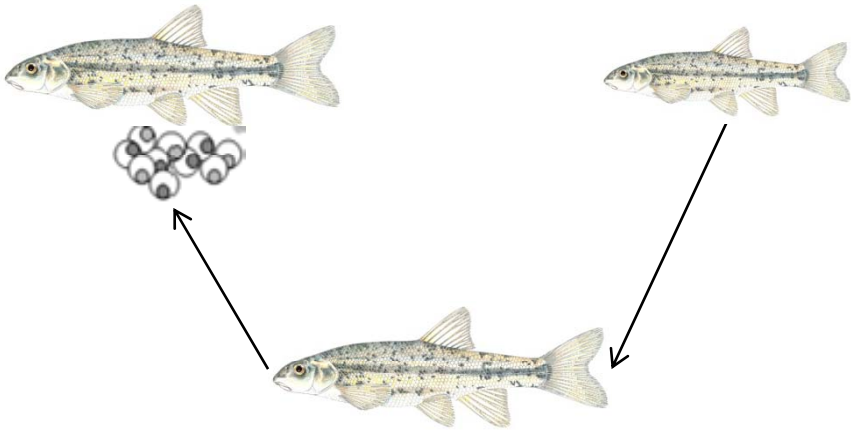
Mechanistic pathway of factors influencing native fish recruitment

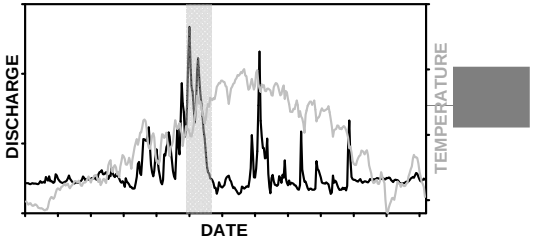


Pre-winter growth
Winter maintenance
- **Stable flows**
- **Minimal biotic interactions**



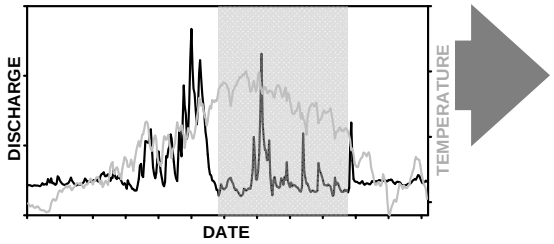
Spring ovary development
- **Timing, magnitude and duration of spring runoff**
- **Temperature**
- **Minimal biotic interactions**



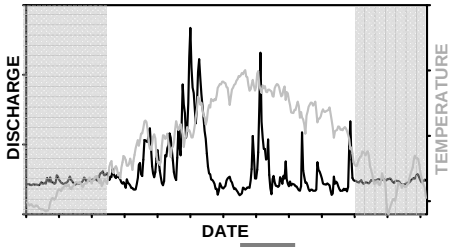


Reproduction
- **Timing, magnitude and duration of spring runoff**
- **Temperature**
- **Egg/larvae predation by nonnatives**

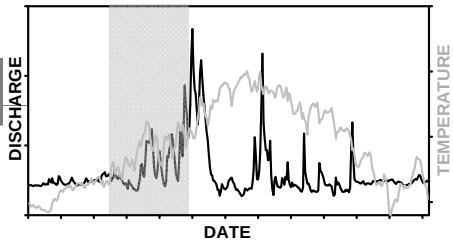
Mechanistic pathway of factors influencing native fish recruitment



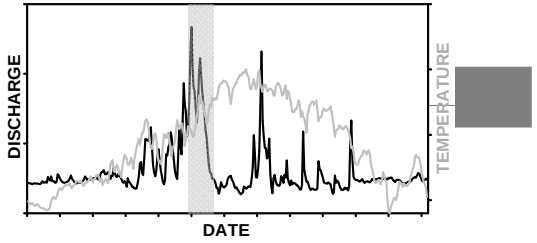
Recruitment
- Summer flows and flow spikes
- Temperature
- Interactions with nonnatives



Pre-winter growth
Winter maintenance
- Stable flows
- Minimal biotic interactions



Spring ovary development
- Timing, magnitude and duration of spring runoff
- Temperature
- Minimal biotic interactions



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- Timing, magnitude and duration of spring runoff
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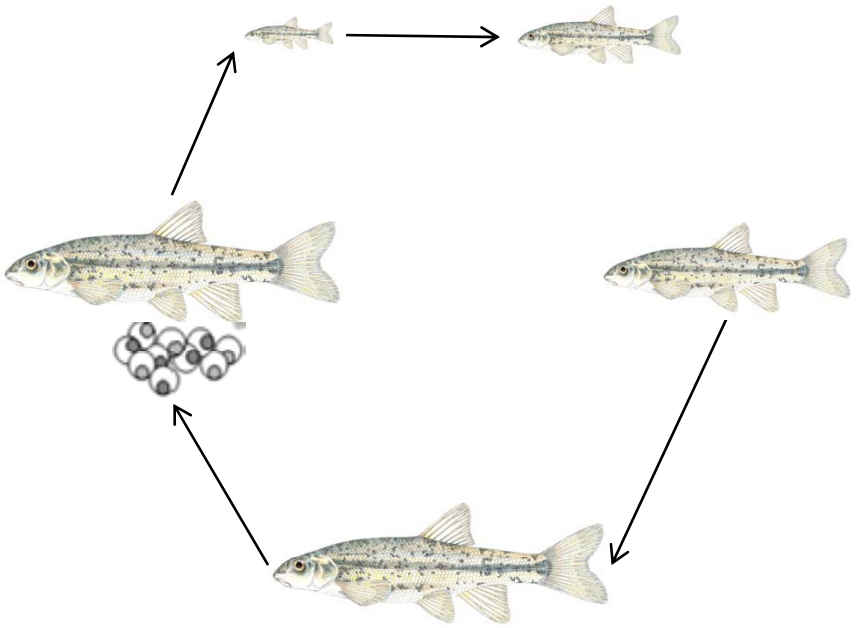
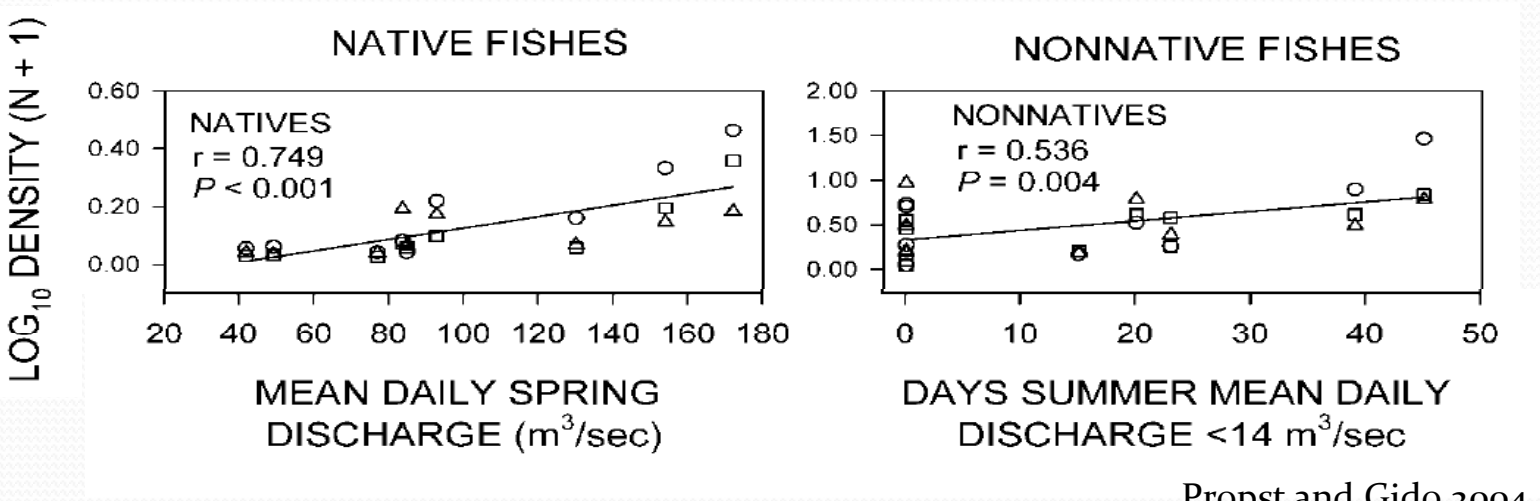


Long-term effects of flow attributes on fish assemblages in San Juan River

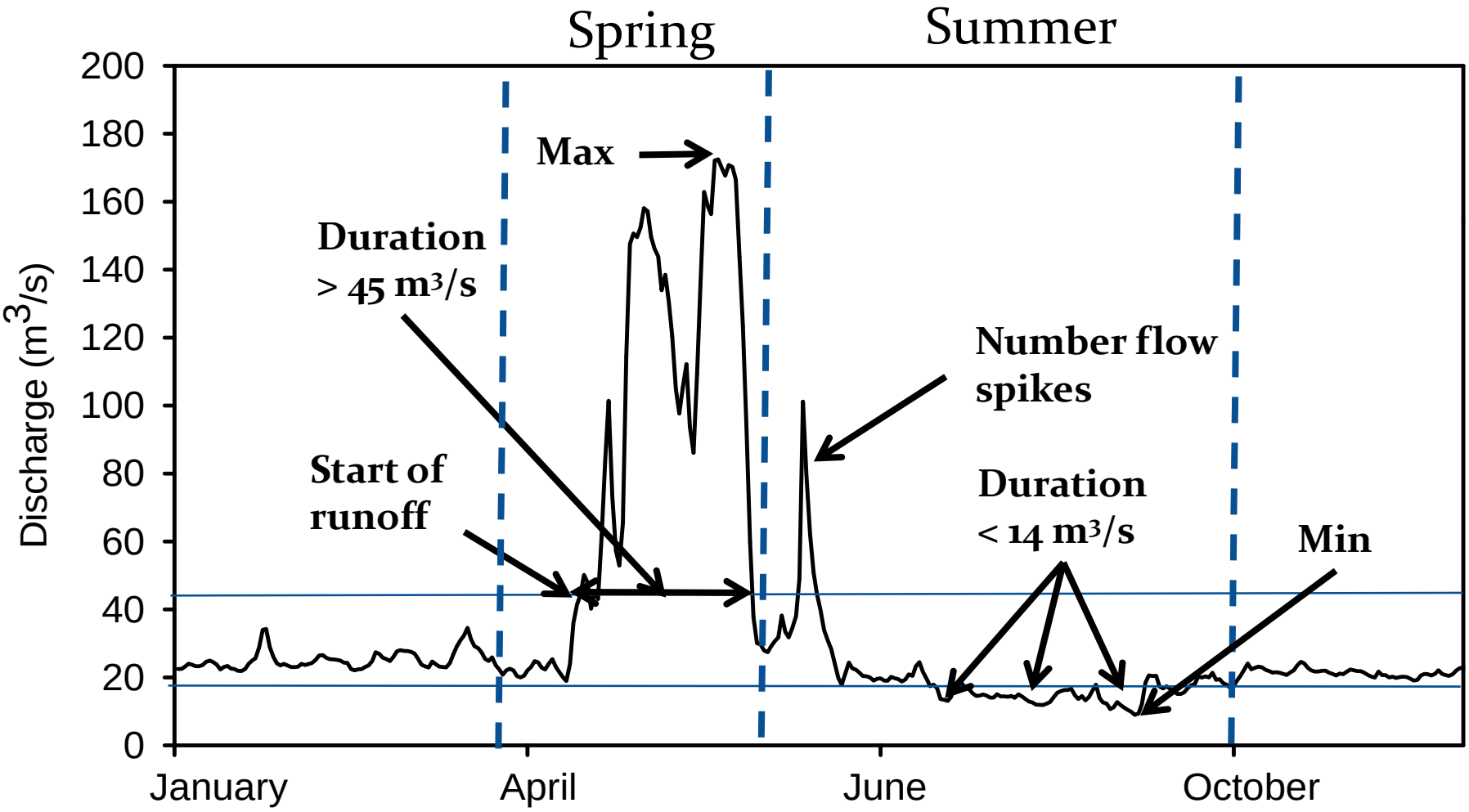
- Model relationship between densities of small-bodied fishes (dependent variable) and annual flow attributes (independent variables)
  - Revisit previous analyses (1993-2001) with new data (1993-2009)



Propst and Gido 2004

- Incorporate nonnative competitors and predators as independent variables in models

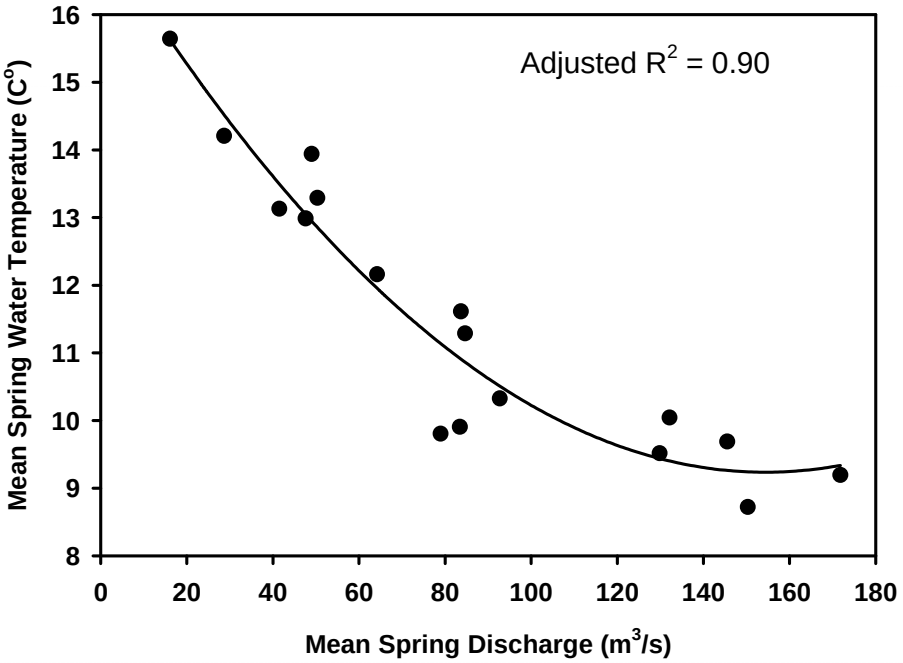
Characterizing annual flow attributes in the San Juan River

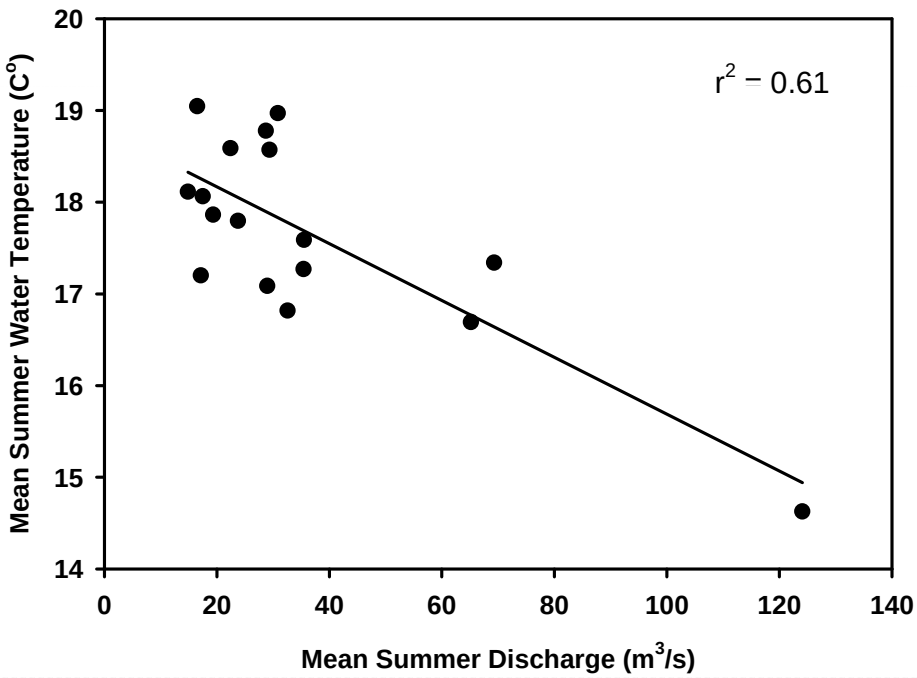


Correlation matrix of flow attributes

	Mean Spring discharge	*Start of runoff*	*Days Q >142 m3/s*	*Max discharge*	*Mean Summer discharge*	*Days Q <14 m3/s*	*Number summer flow spikes*	*Min discharge*
Mean Spring discharge	**1.00**							
Start of runoff	**-0.80**	**1.00**						
Days Q >142 m3/s	**0.94**	**-0.66**	**1.00**					
Max discharge	**0.73**	**-0.39**	**0.67**	**1.00**				
Mean Summer discharge	**0.34**	**-0.18**	**0.29**	**0.35**	**1.00**			
Days Q <14 m3/s	**-0.70**	**0.65**	**-0.62**	**-0.53**	**-0.58**	**1.00**		
Number of summer flow spikes	**0.31**	**-0.23**	**0.23**	**0.36**	**0.85**	**-0.62**	**1.00**	
Min discharge	**0.51**	**-0.32**	**0.45**	**0.44**	**0.83**	**-0.74**	**0.70**	**1.00**

Flows tightly linked to temperature





Fish collections

- Long-term monitoring (SJRIP) from 1993 – 2010
- Small-bodied fish assemblages sampled in October each year in secondary channels with seines
- Nonnative predators sampling in main channel with raft-mounted electrofishing

Data analysis

- Model selection base on ΔAIC_c
  - 16 candidate models for native species
  - 8 candidate models for nonnative species
  - GLS model corrected for temporal autocorrelation
- Bivariate plots examined to evaluate strength and direction of interactions

Model Selection

Number	Model for native species	Category
[1]	Species density~Reach,	**Null**
[2]	Species density~Mean_sp + Reach,	**Flow only**
[3]	Species density~Mean_su + Reach,	"
[4]	Species density~Day_less_14 + Reach,	"
[5]	Species density~Nonnative (Comp) + Reach,	**Nonnative interaction only**
[6]	Species density~Nonnative (Pred) + Reach,	"
[7]	Species density~Nonnative (Pred) + Nonnative (Comp) + Reach,	"
[8]	Species density~Mean_sp + Nonnative (Comp) + Reach,	"
[9]	Species density~Mean_su + Nonnative (Comp) + Reach,	"
[10]	Species density~Day_less_14 + Nonnative (Comp) + Reach,	**Flows + nonnative interactions**
[11]	Species density~Mean_sp + Nonnative (Pred) + Reach,	"
[12]	Species density~Mean_su + Nonnative (Pred) + Reach,	"
[13]	Species density~Day_less_14 + Nonnative (Pred) + Reach,	"
[14]	Species density~Mean_sp + Nonnative (Comp) + Nonnative (Pred) + Reach,	"
[15]	Species density~Mean_su + Nonnative (Comp) + Nonnative (Pred) + Reach,	"
[16]	Species density~Day_less_14 + Nonnative (Comp) + Nonnative (Pred) + Reach	"
	Model for native species	
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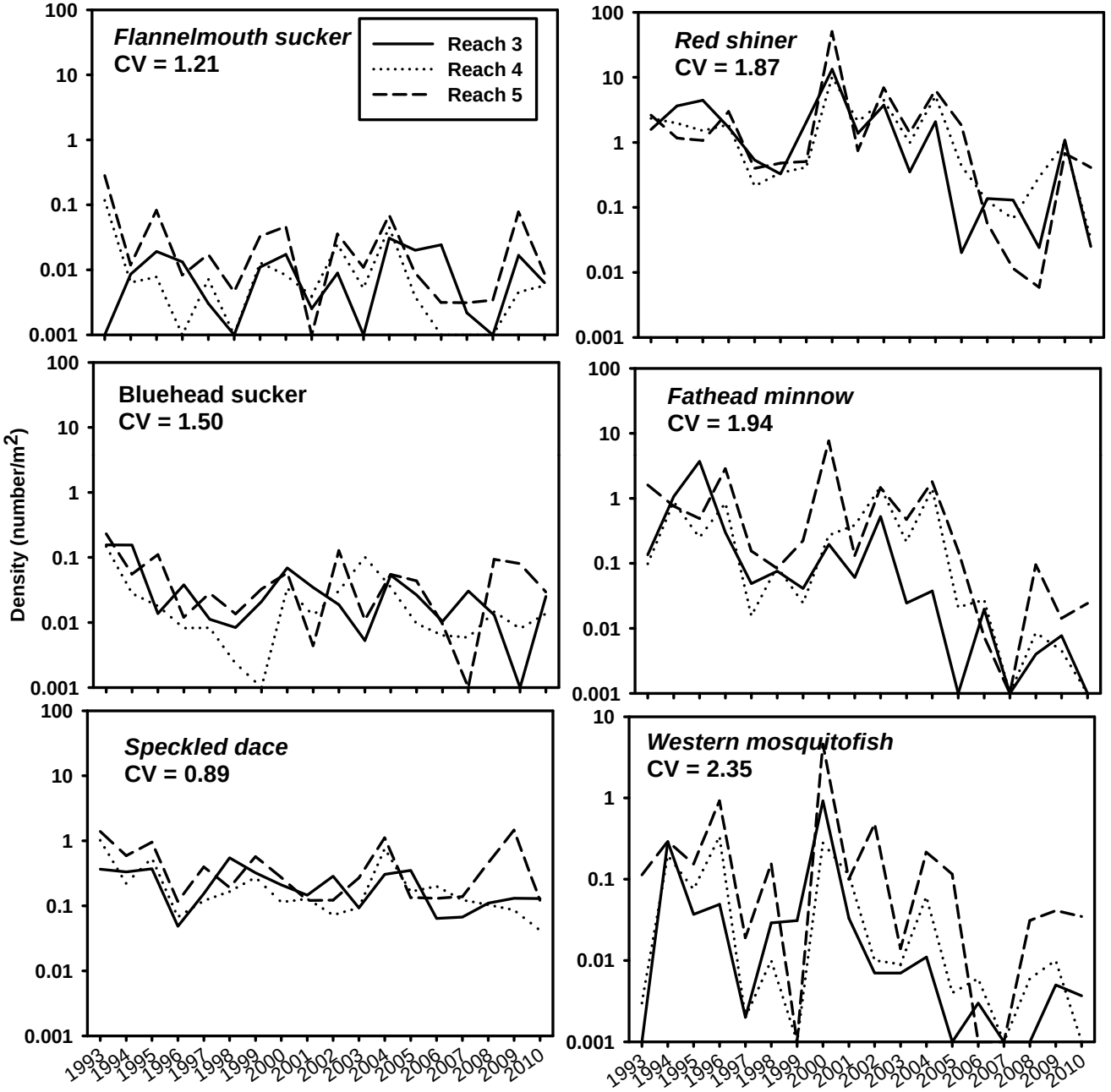
[4]	Species density~Day_less_14 + Reach,	"
[5]	Species density~Nonnative (Pred) + Reach,	**Nonnative predator only**
[6]	Species density~Mean_sp + Nonnative (Pred) + Reach,	**Flow + nonnative predator**
[7]	Species density~Mean_su + Nonnative (Pred) + Reach,	"
[8]	Species density~Day_less_14 + Nonnative (Pred) + Reach,	"

Results

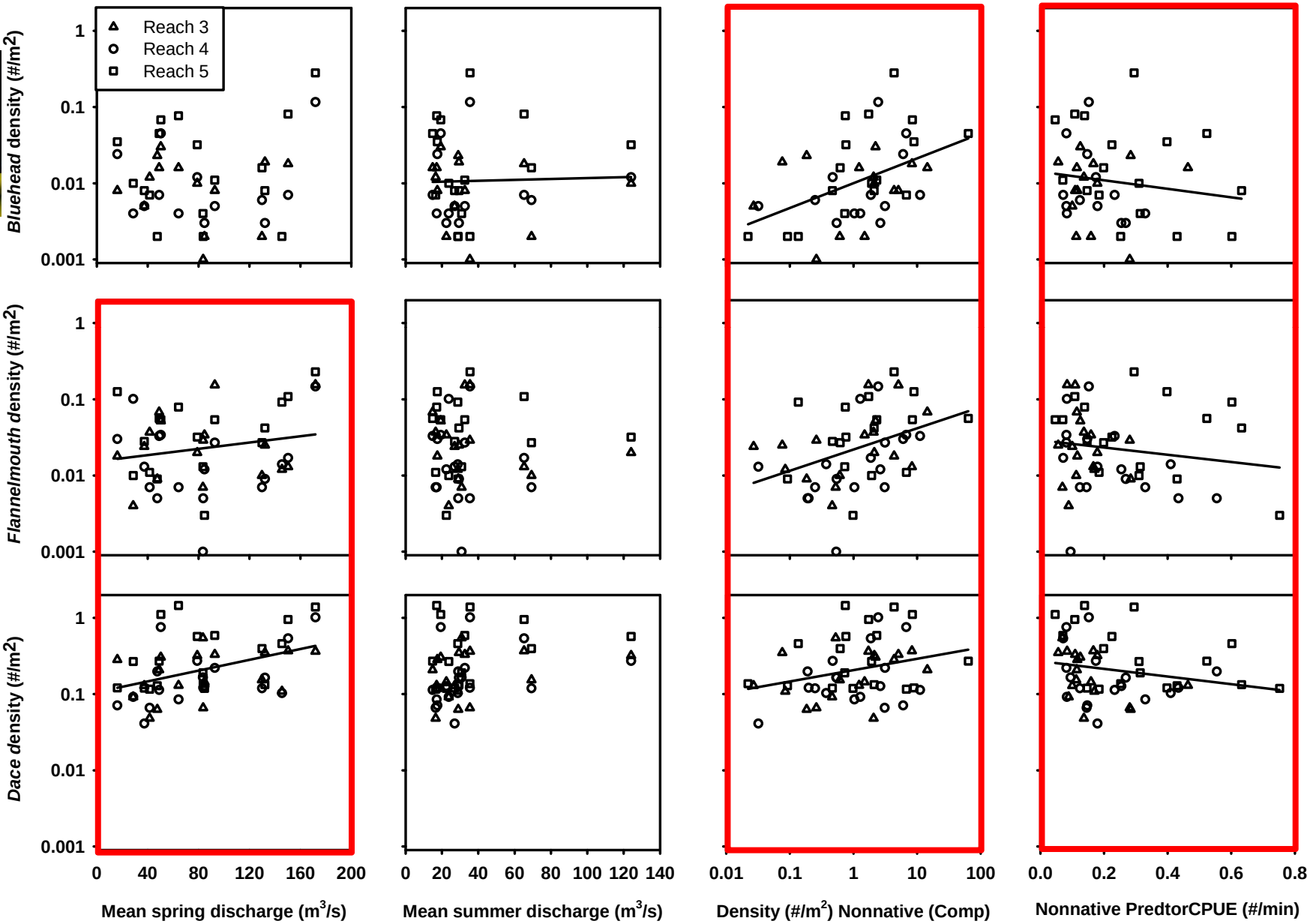
- Native populations relatively stable
- Nonnative population s fluctuations were generally large
- Synchronous variation across reaches



Results: Native fishes

Model	K	AIC_c	ΔAIC_c	w_i	Cum. w_i
Bluehead sucker **(R^2 = 0.273)**					
Nonnative (Pred) + Nonnative (Comp) + Reach	5	183.61	0	0.27	0.27
Mean summer Q+ Nonnative (Comp) + Nonnative (Pred) + Reach	6	184.44	0.83	0.18	0.44
Mean summer Q + Nonnative (Comp) +Reach	5	184.98	1.37	0.13	0.58
Nonnatives (Comp) + Reach	4	185.29	1.68	0.12	0.69
Flannelmouth sucker **(R^2 = 0.286)**					
Mean spring Q + Nonnatives (Comp) + Reach	5	171.73	0	0.35	0.35
Mean spring Q + Nonnative (Comp) + Nonnative (Pred) + Reach	6	172.37	0.64	0.26	0.61
Nonnative (Comp) + Reach	4	173.74	2.01	0.13	0.74
Speckled dace**(R^2 = 0.439)**					
Mean spring Q + Nonnative (Comp) + Nonnative (Pred) + Reach	6	119.55	0	0.76	0.76

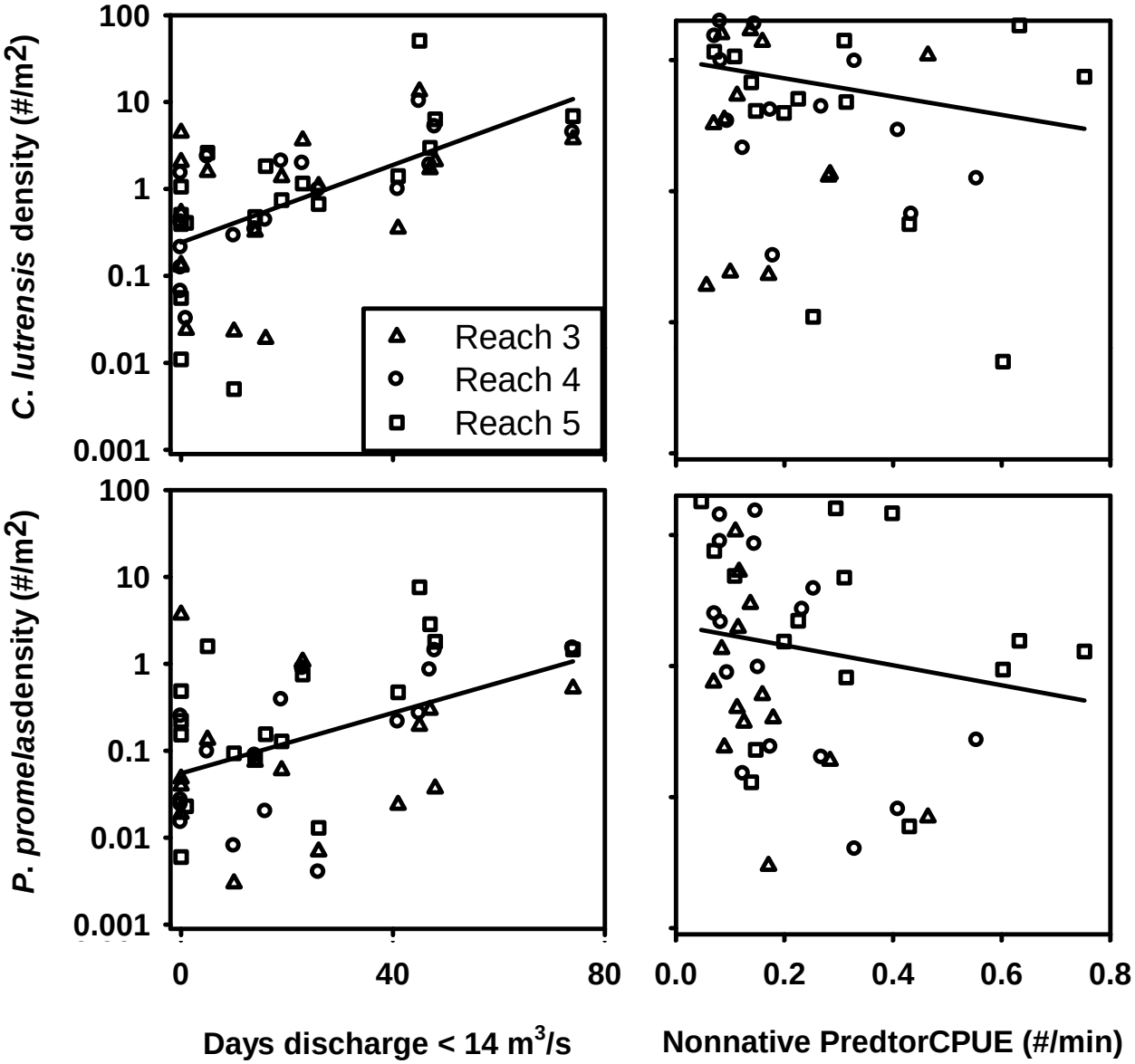
Results: Native fishes



Results: Nonnative fishes

Model	K	AIC_c	ΔAIC_c	w_i	Cum. w_i
Red shiner (R^2 = 0.351)*					
Day < 14 m3/s + Reach	5	192.73	0	0.67	0.67
Day < 14 m3/s + Nonnative (Pred) + Reach	6	194.16	1.43	0.33	1.00
Fathead minnow (R^2 = 0.340)*					
Day < 14 m3/s + Reach	5	203.17	0	0.66	0.66
Day < 14 m3/s + Nonnative (Pred) + Reach	6	204.56	1.39	0.33	0.99
Wester mosquitofish (R^2 = 0.335)*					
Day < 14 m3/s + Reach	5	208.67	0	0.65	0.65
Day < 14 m3/s + Nonnative (Pred) + Reach	6	210.26	1.59	0.29	0.94

Results: Nonnative fishes



Summary of Results

1) Native fish populations more stable than nonnatives
2) 2 of 3 native fishes positively associated with mean spring discharge; partially supports previous analysis base on 9 years of data
   - Bluehead sucker had strong recruitment in low flow year
3) Nonnatives respond positively to low flow duration; also consistent with previous analysis
4) Positive association between native fishes and nonnative competitors
   - No evidence for competition
5) Weak negative association between small-bodied fishes and nonnative predators

Management Considerations

1) Should we manage flows for benefit of natives or detriment of nonnatives?
   - Nonnative competitors do not appear to be a problem and limited response of catfish to flow variation
2) Covariance among flow attributes and temperature makes it difficult to isolate specific attributes for management
   - Conduct experiments that manipulate specific flow attributes
   - Track biological response to flow events on shorter time scale
3) Long-term data necessary to rigorously evaluate assemblage stability during managed flow regime
   - Was stability of natives (or instability of nonnatives) due to mimicry of natural flow regime?

Questions?

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