Benthic macroinvertebrates as indicators of biological condition below hydropower dams on west slope Sierra Nevada streams

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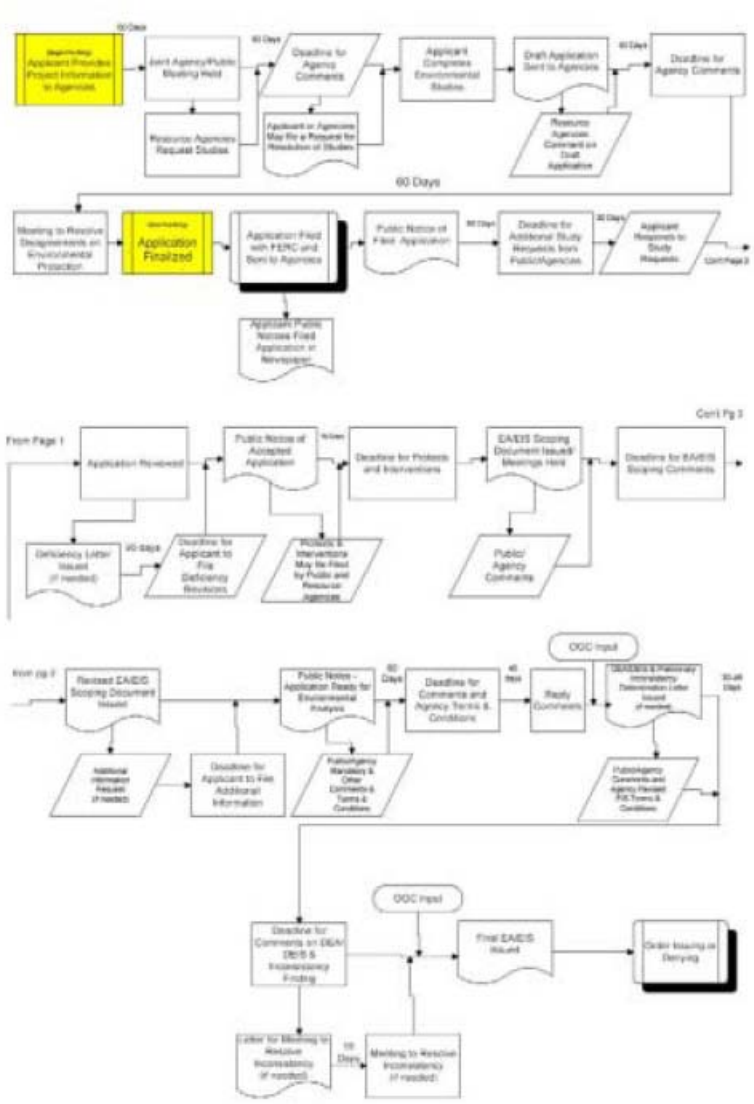
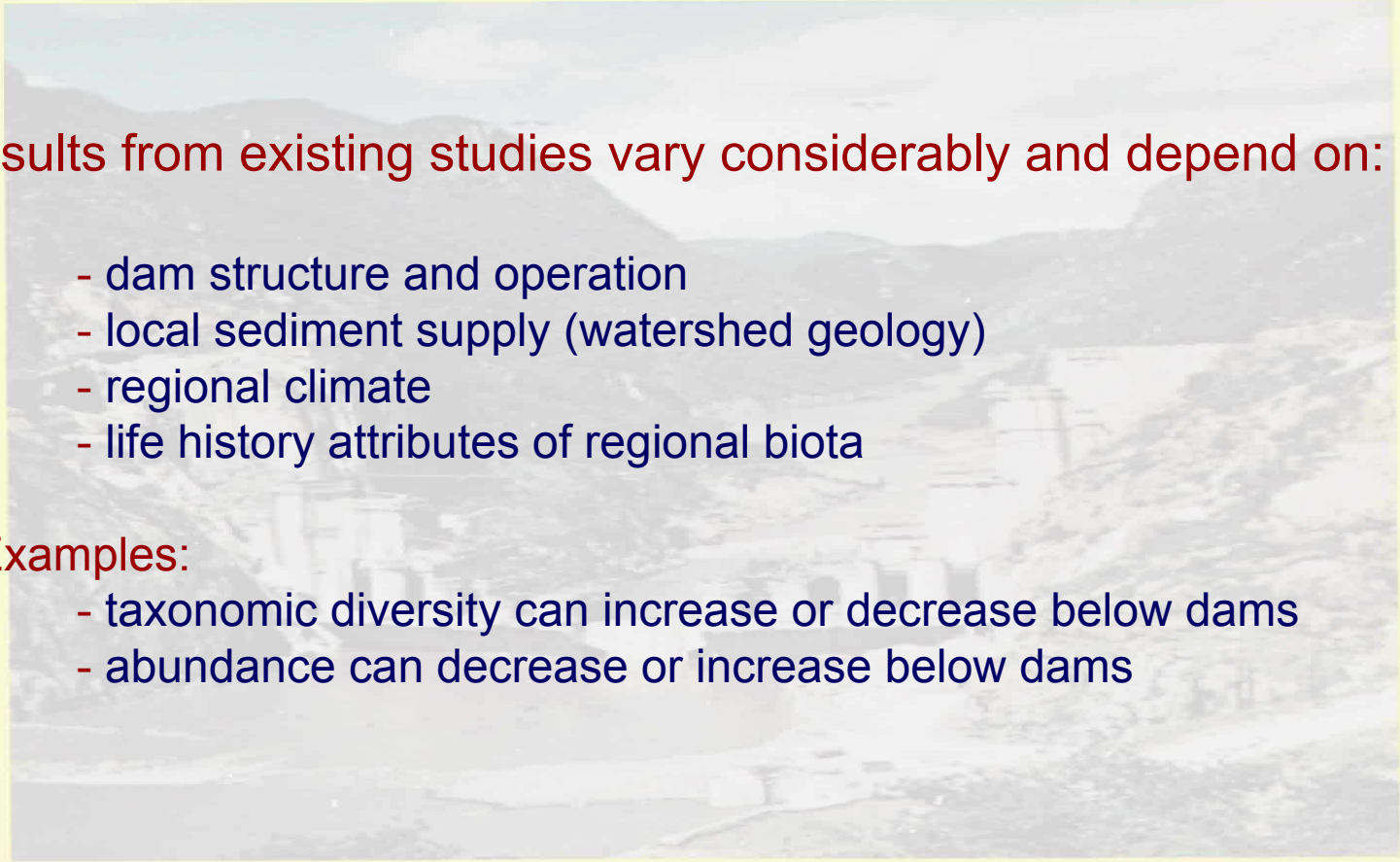
CALIFORNIA STATEWIDE HYDROELECTRIC POWER PLANTS

FERC Relicensing Process:

- 5 year process for each project; every 30-50 years.
- "Equal consideration" given to:
  - water quality
  - fish passage
  - fish and wildlife habitat
  - recreation
- Baseline and mitigation studies often inlcuded



The Ecology of Regulated Streams



Results from existing studies vary considerably and depend on:

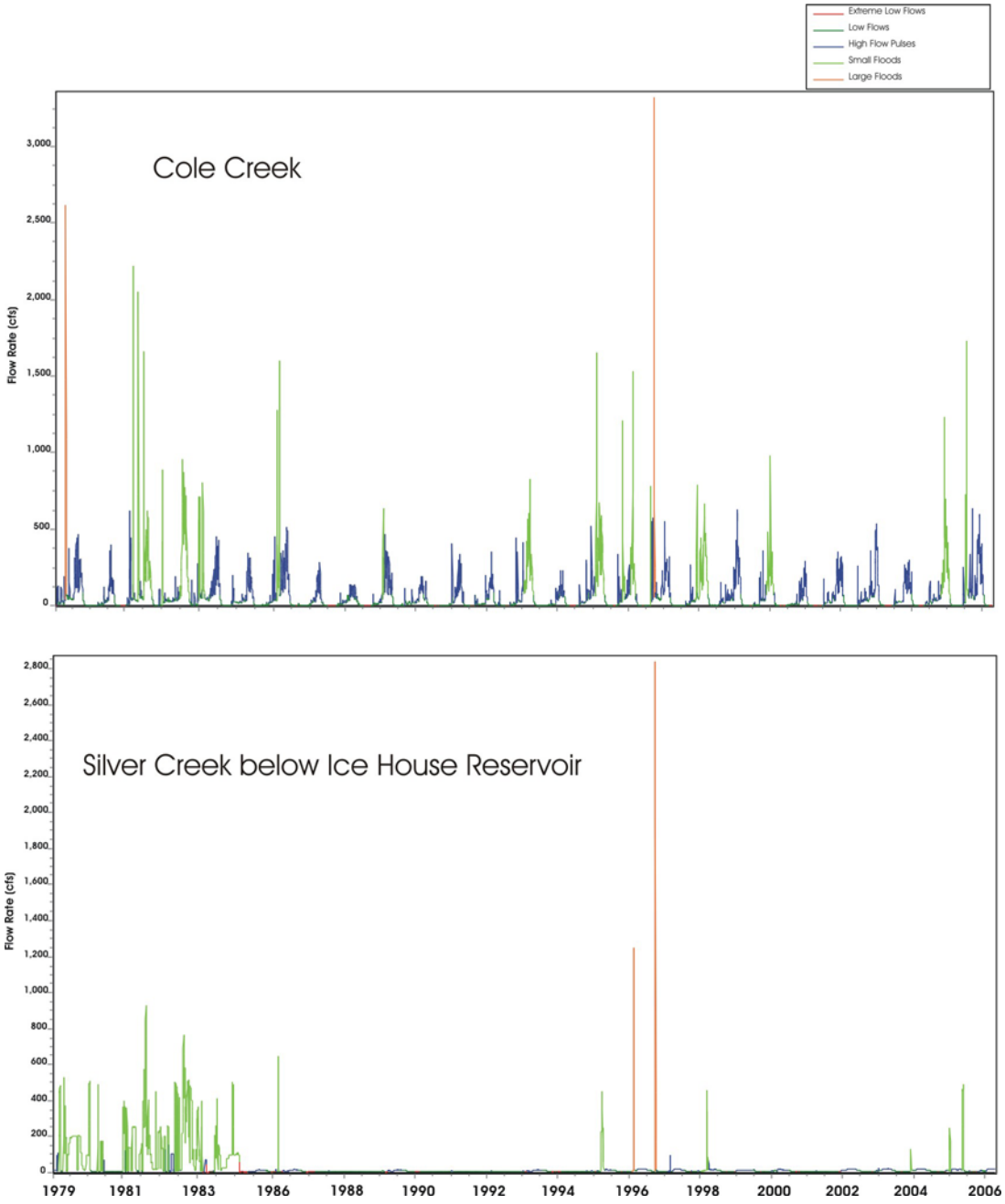
- dam structure and operation
- local sediment supply (watershed geology)
- regional climate
- life history attributes of regional biota

Examples:

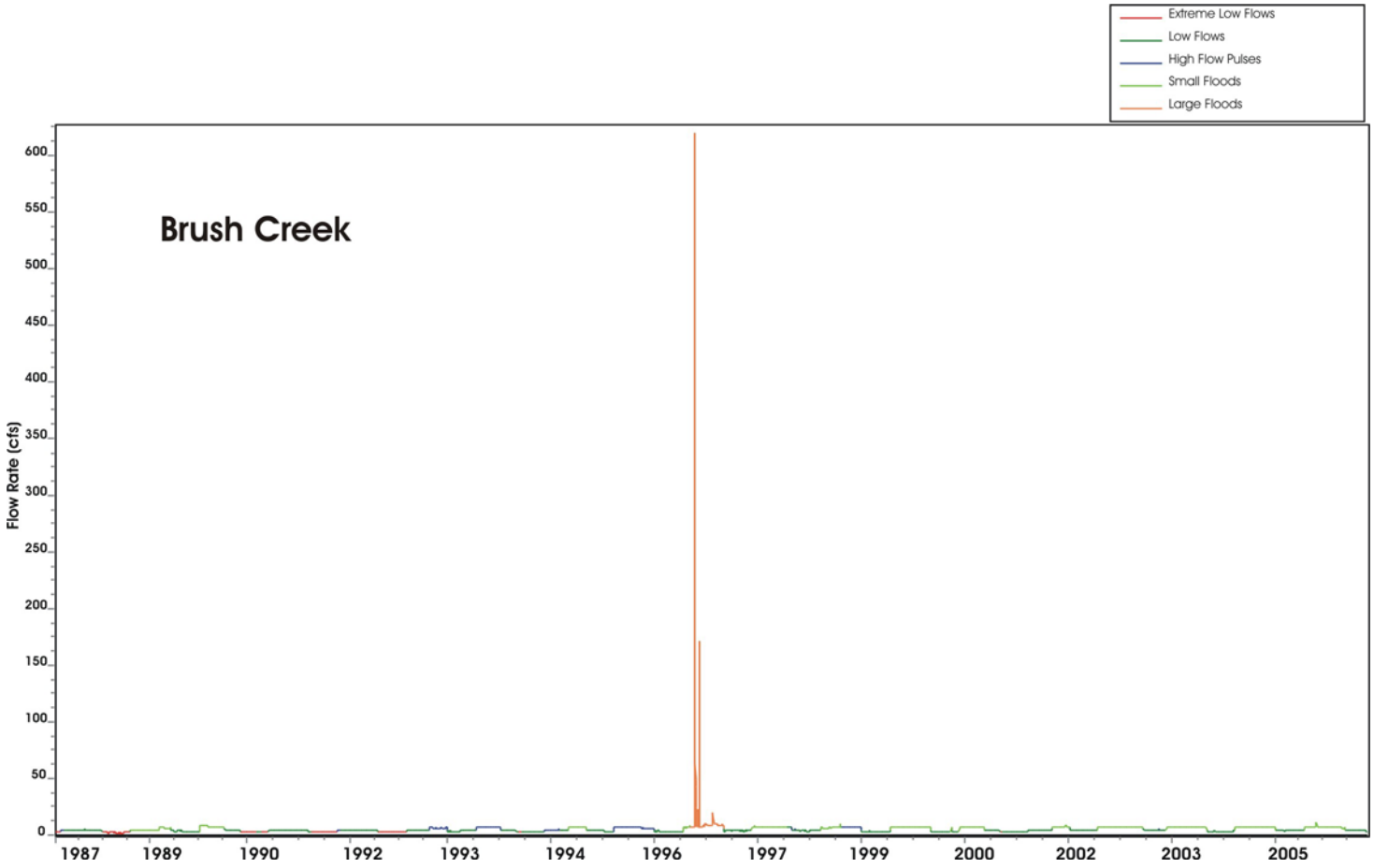
- taxonomic diversity can increase or decrease below dams
- abundance can decrease or increase below dams

Edited by
JAMES V. WARD and JACK A. STANFORD


SOUTH FORK
SAN JOAQUIN RIVER
ELEVATION 6560


Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods
Cole Creek
Flow Rate (cfs)
3,000
2,500
2,000
1,500
1,000
500
0
Silver Creek below Ice House Reservoir
Flow Rate (cfs)
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1979
1981
1983
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006

...major hydrologic alteration!



Questions this study addressed:

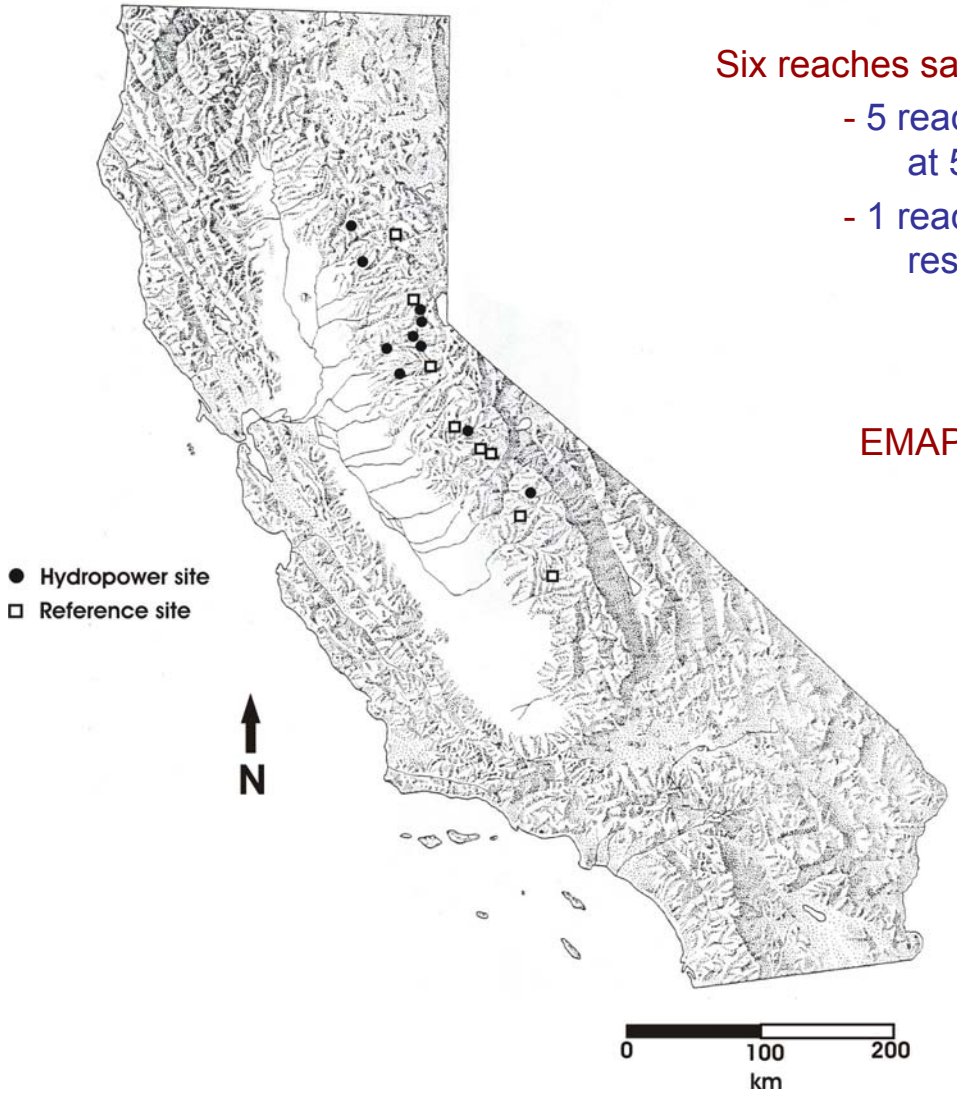
1. Do BMIs respond to stream alterations caused by hydropower dams on west slope Sierra streams, and if so how?

2. Can we build a biological indicator that can be used to help interpret benthic data sets collected in relicensing studies?

3. What is the minimum distance over which biological condition might recover downstream of hydroelectric dams?

4. Can we link BMI responses to potentially controllable physical and hydrological factors that could be used in adaptive management of hydropower operations?

Study Design:



Six reaches sampled at 10 hydropower dams:

- 5 reaches downstream of each dam spaced at 500m intervals
- 1 reach upstream above influence of peak reservoir storage

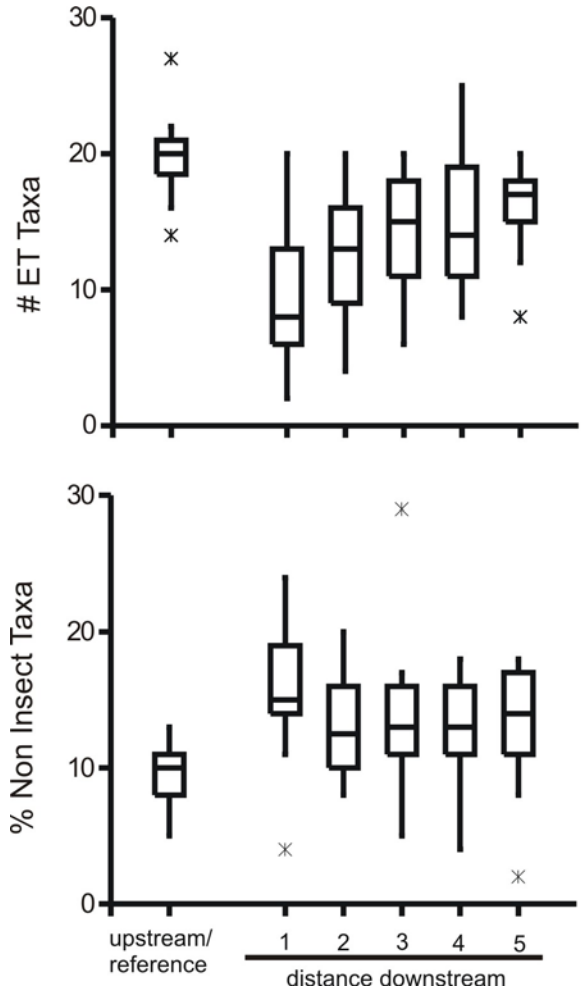
EMAP reachwide sampling protocol used:

- PHAB
- periphyton
- water chemistry for nutrient analysis

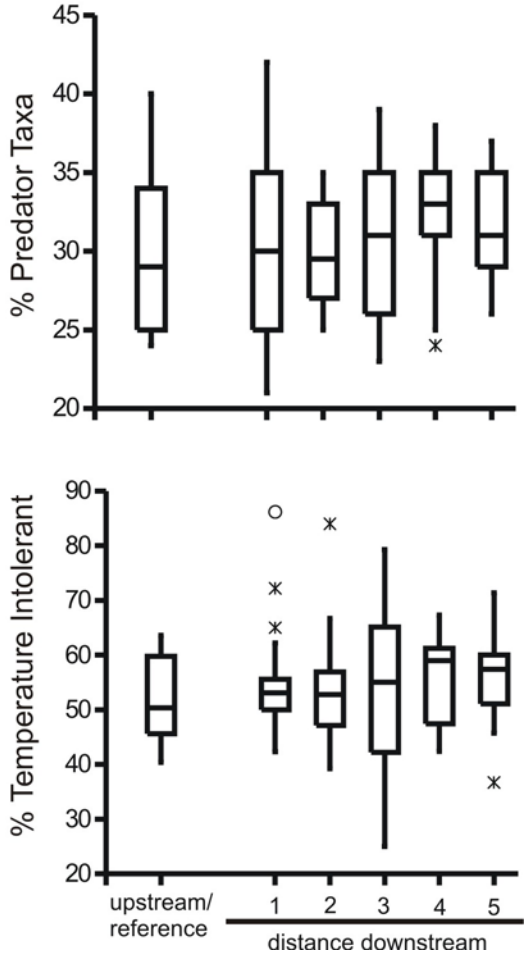
Reference sites:

- upstream reaches
- USFS sites
- EMAP sites

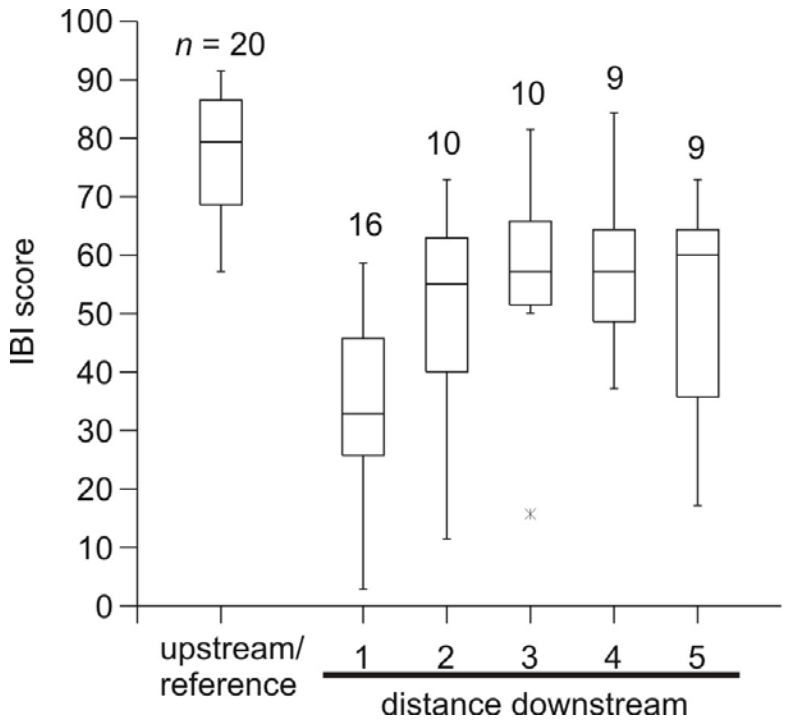
Responsive Metrics



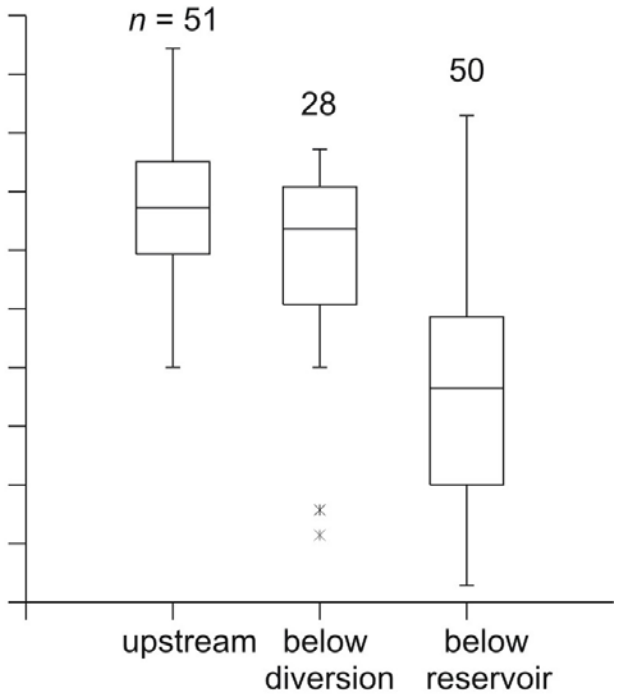
Non-responsive Metrics



Development Set



Validation Set



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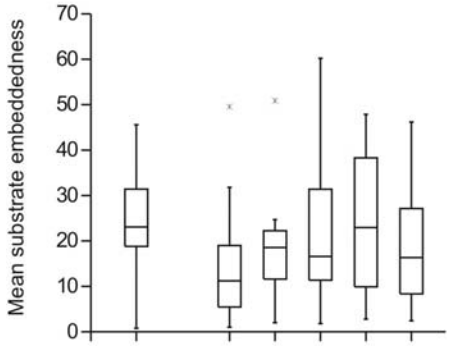
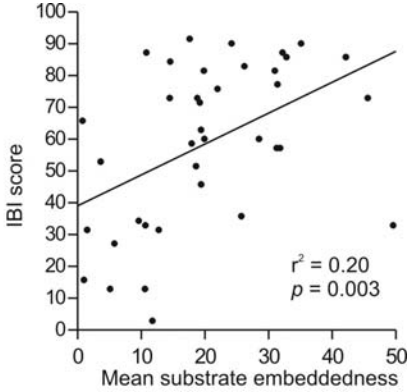
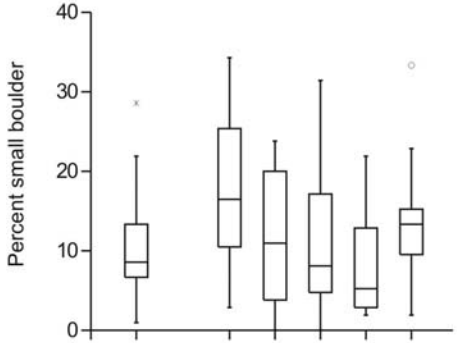
Question 4 Results:

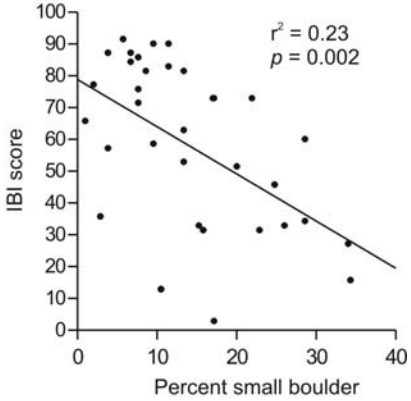
- No relationship between BMI metrics or multivariate NMS axes and physical habitat-channel morphology variables across study reaches:
  - width/depth ratio
  - mean sediment particle size
  - in-stream habitat complexity
  - % pool habitat, % riffle habitat, etc.
  - mid-channel canopy density (but no relationship with proximity to dam)

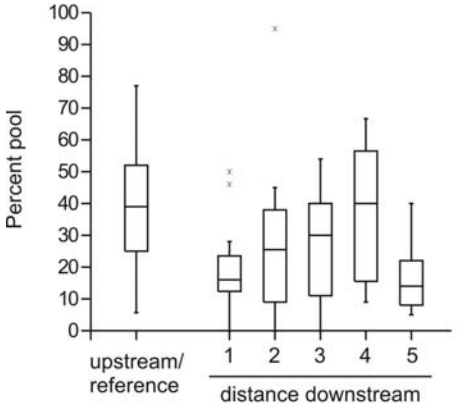
- No difference in nutrients (nitrogen, phosphorous), periphyton AFDM or chlorophyll *a* between upstream and downstream reaches, so eutrophication and algal productivity could not explain observed metric responses.

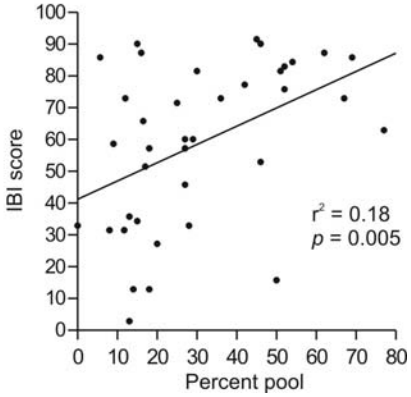

Mean substrate embeddedness
0
10
20
30
40
50
60
70


IBI score
Mean substrate embeddedness
r² = 0.20
p = 0.003
0
10
20
30
40
50
60
70
80
90
100


Percent small boulder
0
10
20
30
40


IBI score
Percent small boulder
r² = 0.23
p = 0.002
0
10
20
30
40
50
60
70
80
90
100

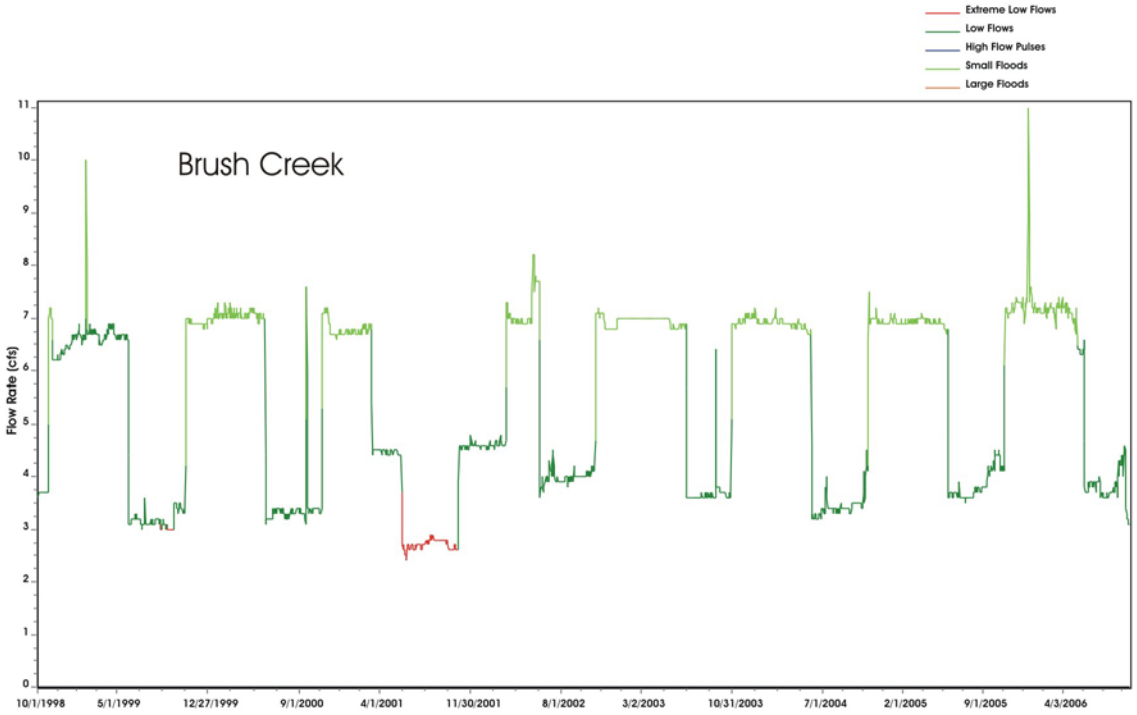

Percent pool
upstream/
reference
1
2
3
4
5
distance downstream
0
10
20
30
40
50
60
70
80
90
100


IBI score
Percent pool
r² = 0.18
p = 0.005
0
10
20
30
40
50
60
70
80
90
100

What about flow regime?

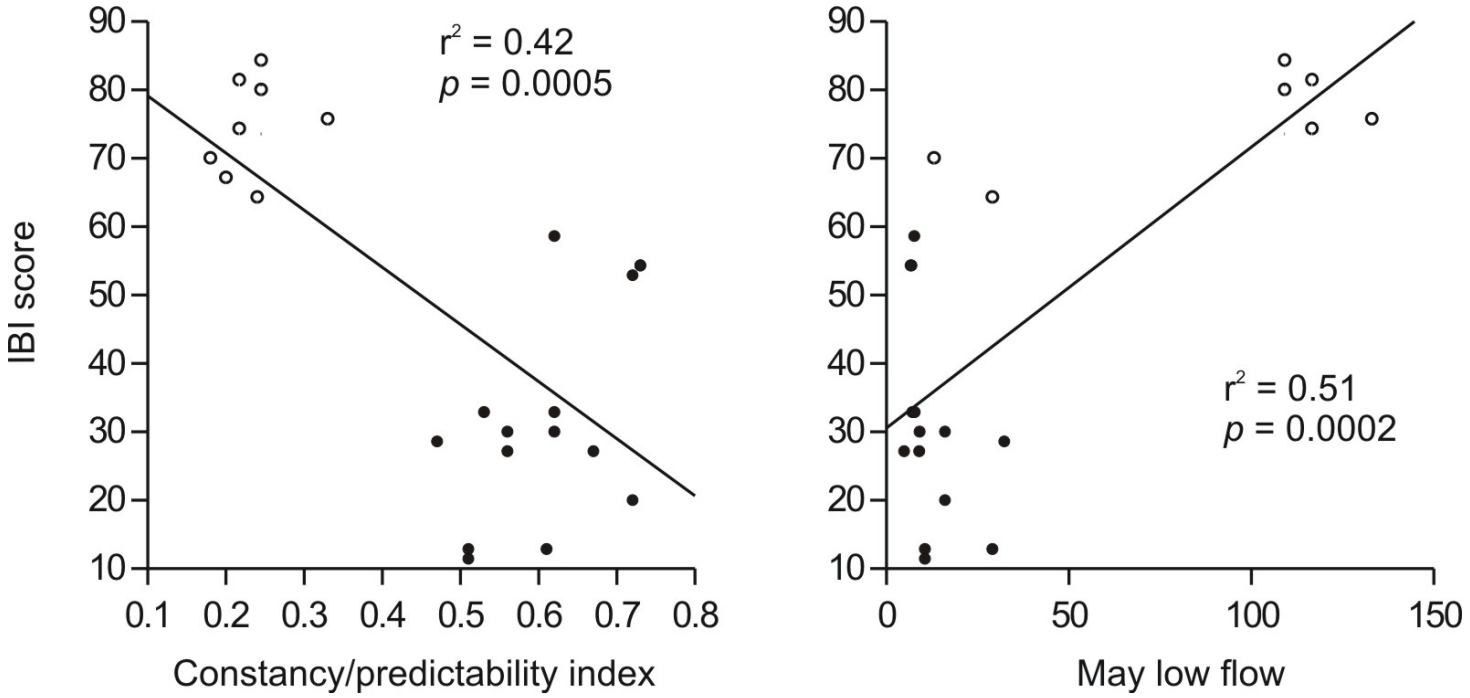
Used Indicators of Hydrologic Alteration (IHA) software to calculate parameters that characterize the magnitude, duration and timing of hydrologic events based on continuous daily flow data.

All dams and a few reference sites had daily flow data.



Constancy-predictability index = C/C+M

where:
C = temporal variance
M = periodicity



Conclusions:

- Hydropower dams on west slope Sierra streams did not have a large effect on channel morphology and in-stream habitat variables.
    - perhaps because of granitic geology with low erosion potential
    - BMI assemblages were mostly non-responsive to in-stream habitat variables
- Decreased IBI scores and shifts in BMI assemblage composition below dams were much better explained by altered flow regime.
- Natural hydrography has become a paradigm for stream restoration based on several disciplines:
    - geomorphology
    - fish ecology
    - macroinvertebrate ecology
- Future relicensing studies should include flow manipulation experiments

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Viewers like you.